Palaeoclimatic oscillations since last deglaciation in western Himalaya : a palynological assay

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The paper embodies the palaeovegetational and palaeoclimatic inferences deduced from the pollen analytical study of lake sediments from Khajiar, Rewalsar, Parasram Tal in Himachal Pradesh and Naukuchia Tal, Sat Tal and Tarag Tal in Kumaon Himalaya. Pollen diagrams from Himachal Pradesh (^{14}C dated to past 3,000 yrs or so) mainly cover later part of the post-glacial climatic optimum, depicting two-fold vegetation change, i.e., oak-chirpine mixed forests to chirpine or deodar forests, reflecting the period of maximum and decreasing warmth respectively in the region. Occurrence of cerealia type pollen together with some other associated elements suggests the existence of agricultural practices in the region.

Similarly, the pollen diagrams from Kumaon Himalaya covering several lakes in Naini Tal District, depict vegetation history during Holocene. At Naukuchia Tal, it commences with chirpine woods, subsequently replaced by broad-leaved forests and then once again it reverts back to chirpine forests. Thus the changing palaeovegetation pattern in the area reflects three-fold climatic fluctuations, viz., cold to warm and again cold. Recently constructed four pollen diagrams from Sat Tal and one from Tarag Tal have revealed the dominance of chirpine-oak mixed forests around 1,000 yrs B.P. as is seen today. The vegetation pattern throughout the sequence remains more or less uniform except for the upper part of lithocolumn depicting slight decline in the arboreal forest components around 500 yrs B.P. or so with simultaneous increase in grasses, sedges and culture pollen which reflect to the anthropogenic activity in this region also.

Key-words—Palynostratigraphy, Palaeoclimate, Kumaon Himalaya, Himachal Pradesh, Quaternary (India).

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सारांश

पश्चिमी हिमालय में पिछले विहिमनदन से पुराजलवायवी उतार-चढ़ाव : परागाणविक समीक्षा

छाया शर्मा

हिमाचल प्रदेश में खजियार, रेवलसार एवं परसराम ताल तथा कुमायूँ हिमालय में नौकुचिया ताल, सत ताल एवं तरग ताल के अवसादों के परागाणविक अध्ययन से पुरावनस्पतिक एवं पुराजलवायवी निष्कर्ष निकाले गये हैं। हिमाचल प्रदेश के परागकण-चित्र पश्चहिमानी जलवायु के बाद के भाग का निरूपण करते हैं तथा ये दोहरा वनस्पति परिवर्तन इंगित करते हैं। इस वनस्पति में ओक-चिरपाइन मिश्रित वनों से चिरपाइन अथवा देवदार वनों की उपस्थिति प्रेक्षित की गई है। कुछ अन्य सहयुक्त अवयवों के साथ-साथ सीरिएलिया प्रकार के परागकणों की उपस्थिति से इस क्षेत्र में कृषि का किया जाना इंगित होता है।

इसी प्रकार कुमायूँ हिमालय के परागकण-चित्र होलोसीन कालीन इतिहास प्रदर्शित करते हैं। इस क्षेत्र के बदलते पुरावनस्पतिक स्वरूप से तिहरा जलवायवी उतार-चढ़ाव प्रदर्शित होता है अर्थात् ठंडे से गर्म और फिर ठंडा। अभी हाल में सत ताल से बनाये गये चार एवं तरग ताल से एक परागकण-चित्रों से लगभग 1,000 वर्ष पूर्व आज ही की तरह चिरपाइन-ओक मिश्रित वनों की बाहुल्यता व्यक्त होती है। पूरे अनुक्रम में एक ही जैसी वनस्पति के होने की झलक मिलती है सिवाय 500 वर्ष पूर्व के आस-पास जबकि वृक्षीय अवयवों की संख्या कुछ कम हो जाती है। यह इस बात का द्योतक है कि इस क्षेत्र में मानव गतिविधियाँ बढ़ गई थीं।

QUATERNARY palaeobotanical research in India commenced in the nineteenth century when Godwin-Austen (1864) for the first time reported the occurrence of leaf impressions in the Lower Karewa deposits of Kashmir Valley. After a gap of about five years Middlemiss (1910) added many taxa as the leaf-impressions. In 1939, De Terra and Paterson published a comprehensive list of plant remains from Lower Karewa, which was followed by Puri

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(1945, 1948a, 1948b, 1957). Recently, Awasthi and Guleria (1982a, 1982b) have added new information on the leaf-impressions and carbonised woods from these beds.

Quaternary palynology in the Indian subcontinent can be traced back to the beginning of this century when Huntington (1906) pollen analysed the sediments from Pangong Lake in Ladakh. However, it was Wodehouse (1935) who initiated the pollen analytical work on the Lower as well as Upper Karewa sediments. Later, Deevey (1937) described fossil pollen spectra from second interglacial sediments of Pangong Lake. In 1948a, Puri carried out the palynological work on some samples from the Karewa beds. Also there are some reports on diatoms and algal remains by Conger (in De Terra & Paterson, 1939), Iyengar and Subramanyam (1943) and Rao and Awasthi (1962).

Palynological investigations at the Institute were taken up in the mid-fifties on the Himalaya (Nair, 1960). The area of investigations covered Assam, Bengal Basin, Garhwal Himalaya, Gujarat, Himachal Pradesh, Kashmir, Kumaon, Ladakh, Maharashtra, Meghalaya, Nilgiris in south, Orissa, Rajasthan, Darjeeling, Sikkim and the adjoining region of Nepal. Palaeovegetation and palaeoclimatic inferences drawn as a result of pollen analytical study of sediments from a number of lakes situated in the subtropical, temperate and alpine zones of Himachal Pradesh and subtropical belt of Kumaon Himalaya have been presented in this paper.

Himachal Pradesh

Pollen analytical investigations in Himachal Pradesh (Sharma, 1970) so far cover about half a dozen lake sites (Map 1). These are Parasram Tal, (district sirmur); Rewalsar, (district Mandi); Khajiar, (district Chamba); Marhi, (district Kulu-Manali); and Batal (Lahul-Spiti districts). The radiocarbon dates of these sites have been given in Table 1.

Table 1—^{14}C dates of various lake sites of Himachal Pradesh

Name of the Site	Depth (in cm)	Sample nos.	Radiocarbon dates
Parasram Tal	70-100	BS-368	680 ± 100
	100-130	BS-170	960 ± 100
	170-200	BS-171	2745 ± 100
	320-350	BS-172	3095 ± 120
	370-400	BS-369	2830 ± 125
	420-450	BS-389	2885 ± 125
	460-490	BS-173	3140 ± 100
Rewalsar I	165-170	WIS-419	520 ± 55
	280-290	WIS-417	1410 ± 60
Rewalsar II	20-40	BS-687	Modern
	170-200	BS-683	Modern
	230-250	BS-684	560 ± 90
	370-400	BS-682	790 ± 80
	520-550	BS-685	980 ± 90
	620-650	BS-703	950 ± 100
	670-700	BS-687	660 ± 120
Khajiar	220-230	WIS-418	1250 ± 60
	450-460	WIS-416	1800 ± 55
	460-470	WIS-428	1830 ± 50
Marhi	37-53.4	BS-87	7985 ± 105
Batal	07-17	BS-54	496 ± 88
	60-67	BS-60	1370 ± 133

Parasram Tal—The lake is situated about 1.5 km east of Dadahu at an elevation of 730 m in subtropical zone. It is almost circular in outline and about 140 m in diameter and can be located just south-west of well known Renuka Lake; both are connected with each other.

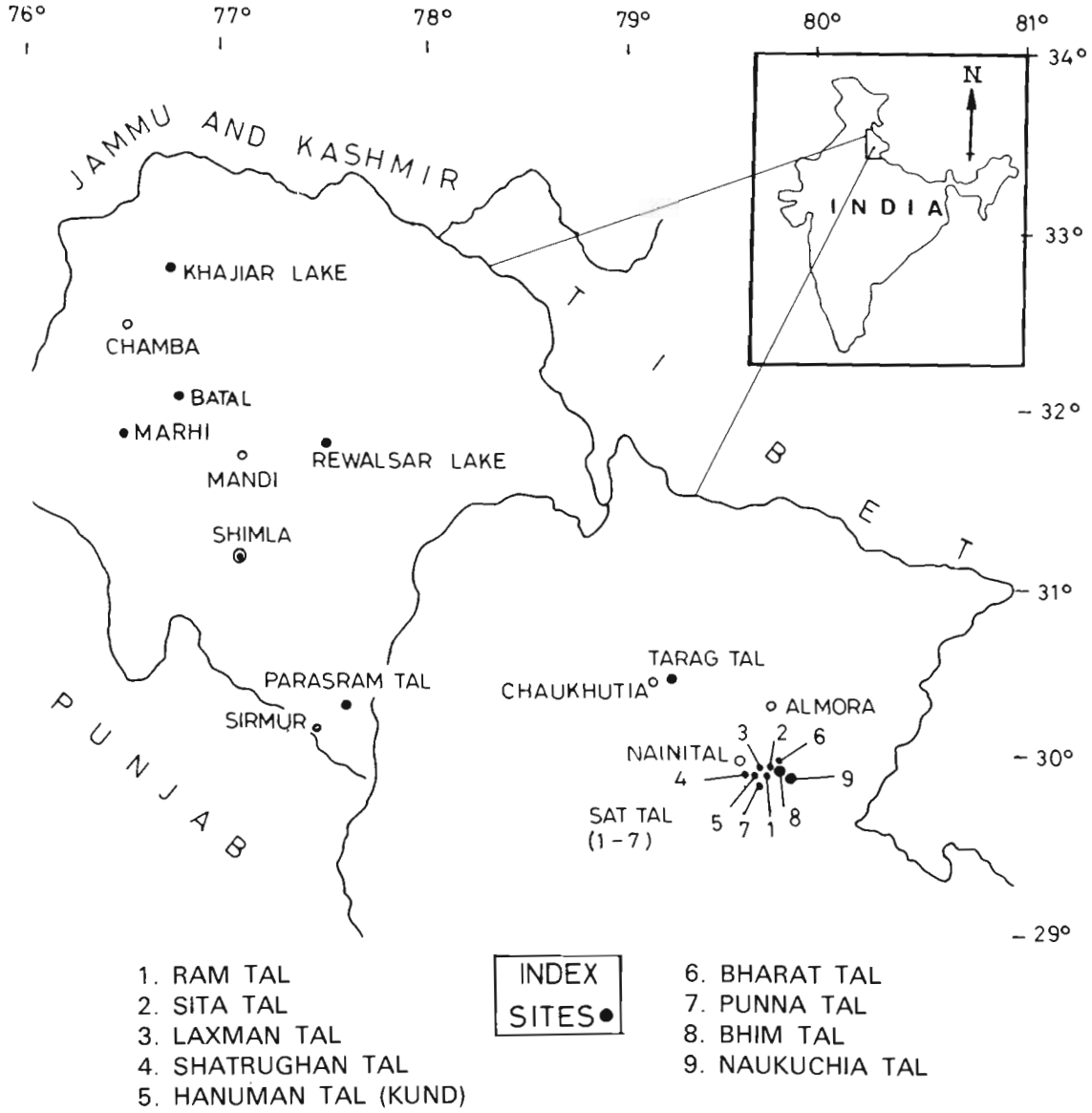
The stratigraphy of nearly 5 m deep profile has broadly shown that the basin is full of peaty deposits, inter-bedded with thin bands of sandy clay at places and embedded shells at the top as well as at the bottom of the dug out column. Further penetration could not be achieved due to the limited capacity of the boring equipment.

Rewalsar I—It is also in subtropical zone and situated about 26 km south-west of Mandi township at an altitude of 1280 m. The lake is more or less triangular in outline with circumference exceeding 1.5 km and is studded with seven main floating islands of various size and shape. The largest one measures 18 m in length and 3.6 m in breadth. Besides a few grasses and sedges, it is mainly populated with tall *Phragmites communis*. This lake is held highly sacred by the Hindus, Buddhists and Sikhs. Its sanctity for the Buddhists is mainly attributed to the presence of floating islands.

The stratigraphy of the infilled part of the lake basin was studied through a series of trial borings made along a section running in the northeast-southwest direction. The lake deposit covering 7.9 m thickness mainly consists of fine and coarse organic detritus, intercalated with silt and clay. Evidence of *Phragmites*-peat, together with silt is seen in the upper half of the deposit in the southwest of cross section.

Rewalsar-II—In contrast to earlier dugout 7.9 m deep profile from the northeast-southwest direction, this profile was collected from east-west direction. But because of hand driven Hiller's peat borer the samples could be collected up to 7 meter depth. The lake basin is full of organic detritus with embedded thin layers of fine or sandy clay except for the upper part which comprises mainly clay.

Khajiar—The Khajiar lake is situated at an



Map 1—Sketch map of Himachal Pradesh and part of Uttar Pradesh showing the lake sites.

altitude of 1950 m in the temperate zone about 13 km north-east of Dalhousie on way to Chamba. It is almost circular in outline and about 60 m in diameter. This lake is also famous for its solitary floating island constituted mainly by organic remains (roots & rootlets, etc.) and covered with *Phragmites communis*. The floating island is oval in outline measuring 15 metre in length and 10 metres in breadth. The lake is also held highly sacred by the local inhabitants due to this floating island and its free movement in the open water.

The stratigraphy of the lake has been studied by analysing the bore-hole samples taken along a line running northwest-southeast direction. The maximum depth reached is 9 metre. The basin is full of *Phragmites* peat intercalated with layers of coarse and fine organic detritus running almost horizontally all through the section.

Marhi—The meadow is situated at an altitude of about 3300 m, in the alpine zone on the left bank of river Beas and south of Rohtang Pass. The meadow site is infact an extensive peaty clay deposit spread over to about 500 sq metres.

A trench was dug in the old lake bed along the bank of a small stream which meets Beas River in the eastern side. The 62.5 cm thick deposit revealed a clear transition between the peaty-clay and the sticky grey-clay.

Batal—This site is situated at an elevation of about 4200 m north of Rohtang Pass just below Konzone La and is known as the flood plateau. This flood plain is actually covered by glacio-fluvial

deposits having sedimentary stratification of various thickness.

A pit about 1.18 m in depth was dug in the boulder free alluvial deposit at the right bank of Chandra River below Konzone Pass. The deposits consist of sediments of various thickness ranging from clay, fine sand, coarse sand to gravel, boulders and pebbles.

ENVIRONMENTAL INFERENCES

The pollen analytical investigations from the beginning of Holocene in Himachal Pradesh have unravelled the vegetation history and climate. The investigated profiles have been grouped into three altitudinal zones namely subtropical, temperate, and alpine to interpret Holocene vegetation and environmental conditions in the western Himalaya (Text-figure 1).

Subtropical Zone

Parasram Tal and Rewalsar pollen diagrams

Zone 1—This zone has been extrapolated to about 3000 yrs B.P. The vegetation picture (Sharma, 1985; Sharma & Chauhan, 1988a, 1988b; Sharma & Singh, 1974b) at the beginning of the zone is seen in a fully developed state with its earlier history remaining concealed in the lithocolumn. The vegetational history begins with mixed Oak-Chirpine forests and these two arboreals enjoyed the dominant and co-dominant positions respectively. The overall dominance of Oak and Chirpine together with other broad-leaved taxa is indicative of warm and moist conditions from the beginning of the investigated profiles.

Cerealia pollen, together with culture pollen, occur simultaneously right from the beginning of the pollen sequences indicating that agriculture practices were in vouge in the region.

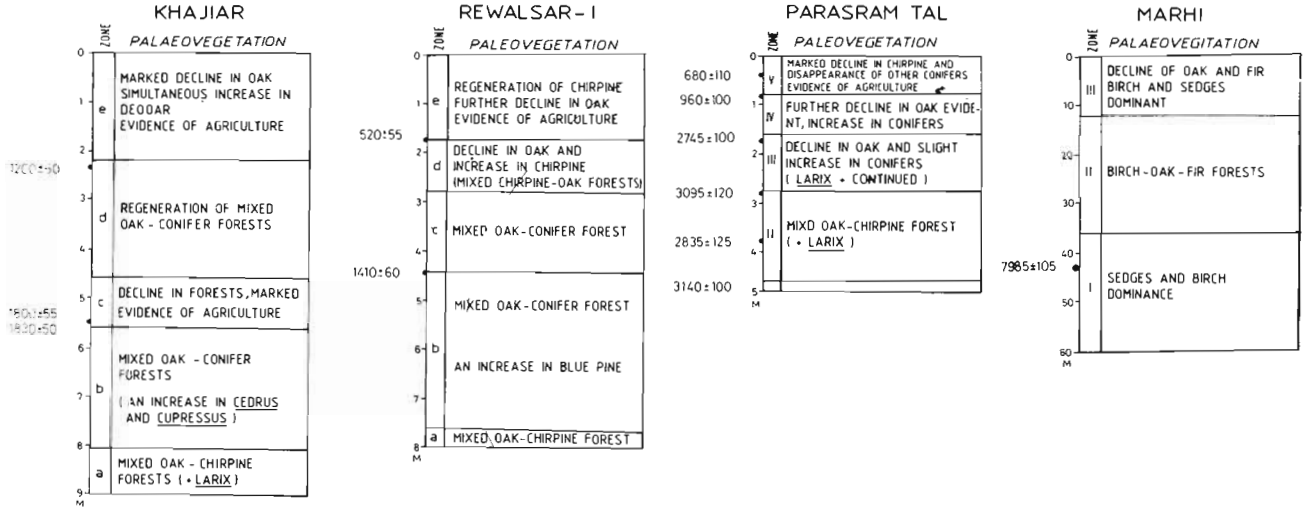
Zone 2—This zone has been dated to 2,000-1,000 yrs B.P. The rise in the values of temperate elements such as *Pinus wallichiana, Abies, Cedrus, Ephedra*, etc. with a simultaneous decrease in Oak and aquatics can perhaps be attributed to changed cool-dry conditions which corroborate by an increase in conifers and simultaneous decline in the taxa growing in wet conditions.

Zone 3—This zone begins with a significantly abrupt fall in Oak and marked increase in the non-arboreal elements, coupled with a prominent sudden fall in the tree and shrub pollen ratios. This catastrophic change in vegetation amply demonstrates increased anthropogenic activity in the area and the clearance of forests on a massive scale probably to bring more land under cultivation. The marked rise in the curve for cerealia together with other culture pollen demonstrates intensive agriculture in the region around 500-600 yrs B.P.

Temperate Zone

Khajiar pollen diagram

Zone 1—In this zone vegetation history around 3,000 yrs B.P. (Sharma & Singh, 1974a) begins with the preponderance of mixed Oak-Chirpine forests, apparently not much different than what is witnessed in the subtropical belt except for the appearance of



Text-figure 1—Comparative study of pollen diagrams from Himachal Pradesh.

some temperate elements. Chirpine pollen, as is represented by its prominent curve, appear to have come from the immediate lower slopes. The analysis of the surface samples (Sharma, 1973) also confirms the transportation of Chirpine pollen from the lower elevations. The overall dominance of Oak is indicative of warmer conditions during this zone.

Zone 2—The date has been extrapolated to 2,000-1,500 yrs B.P., which corroborates the earlier investigated profiles from the subtropical belts of Himachal Pradesh. During this period a change in the trend from mixed Oak-Chirpine to Oak-Conifer forest is evidenced by an increase in the number of conifer taxa reflecting moderate change in the environment from warm to cool conditions, thus favouring a much better growth of conifers.

Zone 3—This zone witnesses a rise in the curves for *Plantago lanceolata*, Cerealia, Apiaceae, Cheno/Ams, etc. accompanied by a fall in the *Quercus* curve and this is indicative of forest clearance, perhaps for agriculture or new settlements in the vicinity of Khajiar around 600 yrs B.P.

Alpine Zone

Marhi and Batal pollen diagrams

Of the two pollen diagrams—one each from Marhi and Batal from this zone, the former is dated to Early Holocene (about 8000 yrs B.P.), and the later, to Late Holocene (Bhattacharyya, 1988). Deeper profiles from these two sites would probably yield a better picture of the past vegetation and climate and may even go beyond Holocene.

Marhi

Zone 1—The pollen spectrum of this zone beyond 8,000 yrs B.P. reflects cool-moist climate in the region. It is evidenced by the presence of Cyperaceae and *Betula* pollen.

Zone 2—This zone, dated to be younger than 8,000 yrs B.P., is characterized by the subsequent migration of *Quercus* and *Abies* in the area and giving rise to a *Betula-Quercus-Abies* community. It is suggestive of upward shift of the forest belt invading even meadows. This migration could have occurred in response to the amelioration of climate later on.

Zone 3—This pollen zone is tentatively dated below 3,500 yrs B.P. The marked increase in Cyperaceae and reduction in arboreal elements in this zone can be ascribed to deterioration of climate. It may also be correlated with the climate deterioration in the plains of Rajasthan (Singh *et al.*, 1972).

Batal—The vegetational history at Batal reveals that prior to 1,800 years B.P. the area was populated by dense *Juniperus-Ephedra* scrub which was subsequently replaced by steppe with *Ephedra* around 1,300 years ago. This lasted until about 800 years when both *Juniperus* and *Ephedra* expanded. Later on by about 500 years it was replaced by *Ephedra* steppe again.

The comparative evaluation and synthesis of a number of constructed pollen diagrams from different altitudes or climatic zones in Himachal Pradesh reveal that broadly the vegetation pattern in this region of western Himalaya is not much different. Vegetational history in each case begins with the Oak-Chirpine mixed forests and all the pollen diagrams are ^{14}C dated to 3,000 yrs B.P. or so, except for the Marhi profile which is from the alpine zone and dated to 8,000 yrs B.P. Cerealia pollen grains together with culture pollen encountered almost from the beginning of pollen sequences indicate human settlement and agricultural activities in the region. Also the two-fold vegetational development depicted in the pollen diagram reflects the period of maximum warmth and the period of decreasing warmth, i.e., the climatic fluctuations and resulting corresponding changes in the vegetation.

The presence of *Larix* pollen right from the beginning of the profiles from Khajiar as well as Parasram Tal dated to 3,000 yrs B.P. and later on its disappearance around 1,500 yrs B.P. is quite interesting in relation to its present sporadic distribution. Based on the available data, it is opined that the Indian Larch (*Larix griffithiana*) may turn out to be a dependable climatic indicator taxon. It is a conifer of selected habitat/climate. A gradual shift in its distribution limits from western Himalaya (where it existed in the past) to further east-wards in Himalaya might be correlated with the changing environment. Palynostratigraphic study has thrown light on the past and present distribution of *Larix griffithiana*. This is the only species which occurs in the Indian subcontinent and at present shows a patchy distribution in Nepal and further east in the Himalaya as compared to its total absence in the western Himalaya (Sharma & Gupta, 1984). Similarly, the recovery of three liverworts—*Sphagnum recurvum* P. Beauv., *Sphagnum* sp. belonging to sect. Sphagnum (Palustre *sensu* Abramova), *Sphagnum* sp. belonging to sect. Cuspidata from Khajiar and Rewalsar profiles deposited around 1,500-2,000 yrs B.P., and *Sphagnum teres* (Schimp.) Aongstr. around 3,000 yrs B.P. from Rewalsar alone and reported earlier from Himachal Pradesh also is very interesting as none of these taxa are known to exist at present in the western Himalaya (Sharma,

1978). The frequent occurrence of *Sphagnum* in the remote past, i.e., 1,500-3,000 yrs ago and its disappearance in the western Himalaya afterwards can be attributed to the unfavourable warmer and drier climatic changes. In fact, it would be worthwhile to explore the area thoroughly to ascertain if these taxa can still be seen in the living state atleast to determine the factors responsible for their total disappearance from such a vast region.

The investigations so far carried out in Himachal Pradesh have also made it possible to uncover the mystery of the origin and development of floating islands, both in Khajiar and Rewalsar lakes (Sharma, 1972). 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' while it is completely absent on the fringes of the lake or even elsewhere in the area within several miles.

This led the author to study the history of 'floating island' at Khajiar through palynological investigations of island and its correlation with the main Khajiar pollen diagram. Its origin is traced back approximately to 700 A.D. At this time presumably it might have detached from the lake margin and started floating in the lake waters.

The pollen analytical investigations of different sites in Himachal Pradesh deal mostly with the later part of Holocene. Deeper profiles are needed to thoroughly understand the vegetational history as well as climatic changes for the entire Holocene Period or beyond.

KUMAON HIMALAYA

Pollen analytical investigations in Kumaon Himalaya deal with four sites around Sat Tal (Ram Tal, Sita Tal, junction of Ram Tal-Sita Tal and Shatrughan Tal), Naukuchia Tal and Tarag Tal. These are situated in the subtropical zone within the outer belt of Himalaya in Uttar Pradesh.

Sat Tal—As the name denotes, Sat Tal is in fact a cluster of seven lakes of different dimensions and amongst them Bharat Tal has completely dried. Sat Tal Valley is situated about 16 km south-east of Naini Tal and 6 km north-west of Bhim Tal with its elevations ranging from 1,350-1,500 m. The cluster of these lakes probably originated long back as a result of the blocking of drainage by major land slides. The reservoir called Sat Tal by local population is a more or less 'Y' shaped lake; its stretched right limb is called as Sita Tal, the left limb is Laxman Tal and the main broad central part is called as Ram Tal. Not too far from Sat Tal situates Shatrughan Tal in the west, which remains dry during the summer months. Adjacent to Sat Tal in the north is another lake—the Panna Tal at a distance of 400 m. This lake is somewhat squarish in shape and lies at the same altitude as is Sat Tal. Yet one more lake—the Hanuman Kund is just a small pond and it lies between Laxman Tal and Shatrughan Tal. Opposite to Shatrughan Tal is seen the dry Bharat Tal which exists today merely as a shallow depression. Of the four lake bottom profiles dug out from the area of Sat Tal—one each from Ram Tal, Sita Tal and junction of Ram Tal-Sita Tal, mainly comprises peat and peaty-clay and do not show any marked variation in their sedimentation or lithology. However, a 3.5 m deep profile from the dried part of Shatrughan Tal is mainly composed of clay, intercalated with organic mud and silty clay.

Naukuchia Tal—As the name implies is a lake having nine corners or contours and lies at a distance of about 4 km south-east of Bhim Tal and 23 km from Naini Tal at an altitude of 1,340 m. The lake is irregular in outline and measures about 950 m in length from north to south and about 670 m broad at its widest. It has a maximum depth of about 50 metres and amongst all the Kumaon lakes, it is the deepest one.

The lake bottom profile of about 6 m depth mainly comprises organic mud, intercalated with clay and sand.

Tarag Tal—This lake is situated at an elevation of 220 m about 10 km east of Chaukhutia. It remains dry during the summers but is flooded during the rainy season. When dry, most of the area of this lake is brought under cultivation for winter crops.

The dug out 1.35 m deep profile mainly consists of clay except for the lower part which is sandy and the upper part is clayey with embedded rootlets.

Table 2—^{14}C dates of various lake sites in Kumaon Himalaya

Name of the Site	Depth (in cm)	Sample nos.	Radiocarbon dates
Shatrughan Tal	90-100	BS-792	Modern
	180-200	BS-793	700 ± 80
	220-250	BS-794	480 ± 80
	250-270	BS-790	750 ± 80
Sat Tal	40-50	BS-157	120 ± 130
	50-60	BS-158	815 ± 80
	120-130	BS-159	940 ± 70
	200-210	BS-160	1400 ± 100
	250-260	BS-160	2400 ± 100
Naukuchia Tal	300	PRL	1404 ± 241
	450	Ahmeda-	3366 ± 265
	580	bad	3005 ± 160

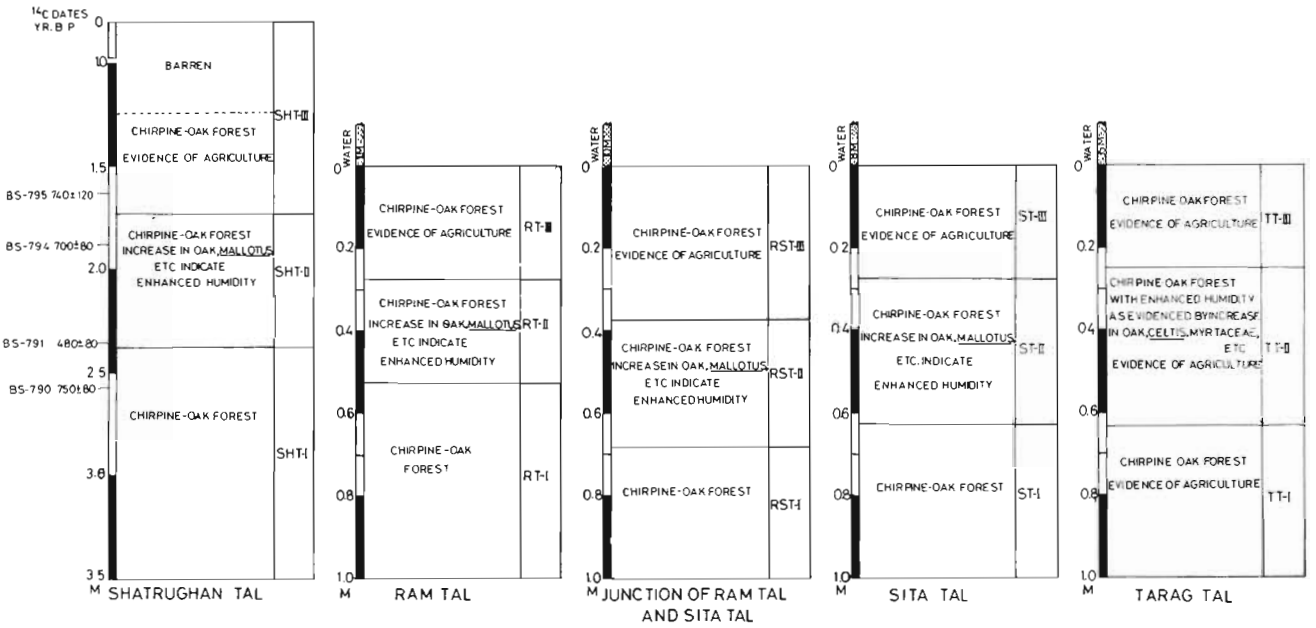
Radiocarbon dates—Among the recently investigated four profiles from Sat Tal area, the ^{14}C dates for only Shatrughan Tal are available as below. The ^{14}C dates provided by Gupta and Khandelwal (1982) for Sat Tal are also provided here, though the actual mini lake or the site is not specified by them. Vishnu-Mittre *et al.* (1967) and Gupta (1977) investigated two lakes sites—Naukuchia Tal (Kamal Tal) and Bhim Tal but did not provide the radiocarbon dates.

Environmental Inferences

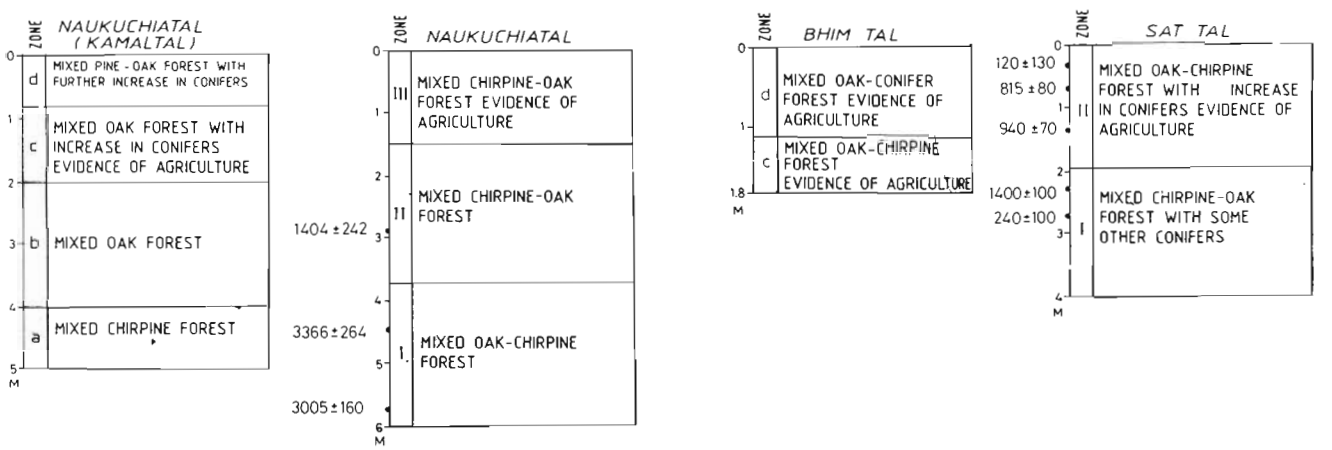
The pollen analytical investigations carried out in subtropical belt of Kumaon Himalaya have unravelled a part of vegetation history and climate of Holocene epoch only (Text-figures 2, 3).

Sat Tal and Tarag Tal

Five pollen diagrams constructed one each from Ram Tal, Sita Tal, junction of Ram Tal-Sita Tal, Shatrughan Tal and Tarag Tal depict the vegetation pattern covering the last 1,000 yrs B.P. (Sharma & Chauhan, MS). On the basis of significant variations in the overall vegetational assemblages, three pollen zones are recognised in each pollen diagram from the region which correspond with each other in



Text-figure 2—Correlation of pollen diagrams from different lake sites in Sat Tal and Tarag Tal.



Text-figure 3—Comparative study of pollen diagrams from Kumaon Himalaya.

main aspects.

Pollen zone 1—The zone is ^{14}C dated to 1,000 yrs B.P. and is characterized by the dominance of Chirpine over Oak and other broad-leaved taxa suggesting the existence of mixed Chirpine-Oak forest. The overall pollen assemblage reflects warm temperate climate in the region.

Pollen zone 2—In this zone there is a slight decrease in the frequencies of Chirpine pollen and corresponding increase in Oak together with *Mallotus* and other broad-leaved taxa. This is probably due to a slight change in the climate, i.e., more moist than before.

Pollen zone 3—This zone is marked by a decline in Oak, *Mallotus* and other broad-leaved elements with a simultaneous increase in grasses, sedges, Cheno/Ams and Asteraceae. Other culture pollen indicate hectic anthropogenic activities in the region around 500 yrs B.P. or so, and this very well corroborates with the commencement of new settlements in many accessible parts of Kumaon Himalaya in the recent past.

Naukuchia Tal

Recent pollen diagram from the lake bottom sediments of Naukuchia Tal (Sharma & Chauhan, MS) reveals that about 4,000 yrs B.P. the mixed Oak-Chirpine forests dominated these mountains. It is evidenced by the dominance of Oak pollen frequency, followed by Chirpine and other broad-leaved elements like *Betula, Ulmus, Rhododendron, Juglans, Celtis, Salix, Mallotus, Emblica*, Myrtaceae, etc. Such a composition of the arboreal taxa indicates well established forests in the region as well as prevalence of warm temperate and humid climate. Subsequently, around 1,000 yrs B.P. Chirpine dominated over Oak in these forests probably as a result of less humid climatic conditions than before. Increase in grasses, Cheno/Ams, *Artemisia, Plantago*, etc. towards the top of the pollen diagram (around 500-600 yrs B.P.) indicates anthropogenic activities in this region also and this picture is identical with that which emerged from Sat Tal and Tarag Tal.

Thus, the present investigations of the lake sediments from Sat Tal area amply demonstrate that the existing present cluster of seven adjoining or closely situated water-filled depressions or mini lakes—one of them already a dried up lake bed, must have been a single lake of large dimension or a continuous water expansion in the past. The formation of these clustered mini lakes, in all probability, might be the result of either decline in monsoon precipitation in this region or due to the local land slides during the past.

Similarly, the present palynostratigraphical investigations of Quaternary section exposed at Bilaspur and situated in between Bhim Tal and Naukuchia Tal have revealed the existence of a lake in the remote past in the area. This leads one to infer that in all probability, the present two lakes—Bhim Tal and Naukuchia Tal, now separated by the Bilaspur landmass, might have been a vast water expansion or a mega-lake in the past (> 40,000 yrs B.P.). But, probably as a result of catastrophic landslides in the region or the tectonic up-heavals, this mega-lake got splitted into the existing Bhim Tal and Naukuchia Tal which are situated four kilometer apart and separated by the Bilaspur landmass.

It is felt that systematic survey and selection of additional lake sites in the Himalaya, probably in the central and eastern belts, can guide us to depict the past vegetation sequences to decipher the corresponding climate covering the entire Quaternary Period. This is of absolute importance to the environmentalists to understand the present climatic behaviour—regional as well as global, for making more dependable climatological predictions.

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