Palaeobotanist 49 (2000) : 501-507
0031-0174/2000/501-507 $2.00

Vegetation and climate in Garhwal Himalaya during last 4,000 years

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(Received 22 December 1999; revised version accepted 24 August 2000)

ABSTRACT

Sharma C, Chauhan MS & Rajagopalan G 2000. Vegetation and climate in Garhwal Himalaya during last 4,000 years. Palaeobotanist 49(3) : 501-507.

Pollen analysis of 3 metre dug out trench (Profile-I) from Deoria Tal, situated at an altitude of 2,727 m a.s.l. in Garhwal Himalaya has revealed that 4,000 yrs ago the vegetation was dominated by Oak forests, associated with other broad-leaved elements such as *Alnus, Rhododendron, Betula* and *Ulmus*, together with shrubby elements-*Viburnum*, Rosaceae and Oleaceae. It reflects to the warm temperate and humid climate prevailing in the region. Pollen of *Pinus roxburghii* in the sediments is attributed to their transport to the lake site from the surrounding lower elevations where the Chirpine forests exist. The inference is well corroborated by the study of large number of surface samples gathered from different altitudes and ecological situations in Garhwal Himalaya (Sharma, 1985a). Decline in *Quercus* together with its associated broad-leaved taxa is witnessed during 3,200-1,700 yrs BP with a corresponding increase in grass pollen. It demonstrates the deterioration in the climate which turned less moist than before. The climatic change is further corroborated by the simultaneous expansion of Chirpine forests in the neighbouring lower hill slopes. Around 1,700 yrs BP, amelioration in climate to earlier existed condition is registered as evidenced by increase in *Quercus* and other associated broad-leaved taxa.

Though the evidence of anthropogenic activities is noticed right from the beginning of the sequence, but intense agricultural practices around 3,000 yrs BP, is evidenced by enhanced frequencies of pollen of grasses, Cheno/Am, Brassicaceae, *Artemisia* and Urticaceae, supported by the frequent recovery of charcoal pieces from the succession.

Key-words—Late-Quaternary, Palynostratigraphy, Palaeovegetation, Palaeoclimate, Garhwal Himalaya.

विगत 4,000 वर्षों के दौरान गढ़वाल हिमालय की वनस्पतियाँ एवं जलवायु

छाया शर्मा, मोहन सिंह चौहान एवं गोविन्दराजा राजगोपालन

सारांश

गढ़वाल हिमालय में समुद्र तल से 2,727 मीटर ऊँचाई पर अवस्थित देवरिया ताल में खोदी गयी 3 मीटर की खाई (परिच्छेदिका-1) के परागाणविक विश्लेषण से प्रदर्शित होता है कि 4,000 वर्ष पूर्व यहाँ की वनस्पतियों में ओक वनों के साथ-साथ चौड़ी पत्तियों वाले तत्वों, जैसे *एल्नस, रोडोडेन्ड्रॉन, बीटुला* एवं अल्मस के साथ झाड़ीदार तत्वों, जैसे- *वाइबर्नम*, रोसेसी एवं ओलिएसी की प्रमुखता थी. इससे क्षेत्र में उष्ण तापमान एवं आर्द्र जलवायु का होना प्रदर्शित होता है. अवसादों में *पाइनस रॉक्सबर्गाइ* के परागकणों की उपस्थिति आस-पास के अधो उच्चताओं में पाए गए चीड़ के वनों से झील स्थलों की ओर परिवहन के कारण है. यह अनुमान गढ़वाल हिमालय की विभिन्न ऊँचाईयों तथा पारिस्थितिकीय स्थितियों से एकत्र किए गए अनेक पृष्ठीय नमूनों के अध्ययन (शर्मा 1985 ए) द्वारा निकाला गया है. 3,200-1,700 वर्ष पूर्व के दौरान घास

परागकणों में संगत वृद्धि के साथ *क्वर्कस* से युक्त चौड़ी पत्तियों वाले वर्गकों में कमी प्रदर्शित हुई है. इससे जलवायु में अवनति प्रदर्शित होती है, जो पहले की अपेक्षा कम नम हो गई थी. जलवायु में अग्रगामी परिवर्तन की पुष्टि समीपवर्ती अधो पहाड़ी ढलानों में चीड़ के वनों के समकालिक विस्तार से होती है. 1,700 वर्ष पूर्व के आस-पास जलवायु में पूर्व की परिस्थितियों की तुलना में सुधार दृष्टिगत होता है, जिसके प्रमाण *क्वर्कस* तथा अन्य सहयोगी चौड़ी पत्ती वाले वर्गकों में वृद्धि द्वारा देखे जा सकते हैं.

यद्यपि अनुक्रम में प्रारम्भ से ही मानवोद्भवी गतिविधियों के प्रमाण मिले हैं, तथापि 3,000 वर्ष पूर्व के आस-पास ही गहन कृषि सम्बन्धी कार्यों के प्रमाण मिलते हैं. इसकी पुष्टि अनुक्रम से प्राप्त चारकोल के टुकड़ों की यदा-कदा प्राप्ति द्वारा समर्थित घास के परागकण, चीनो/एम्स, ब्रासीकेसी, *आर्टीमीज़िया* एवं अर्टीकेसी की वर्धनशील आवृत्तियों होती है.

संकेत शब्द—अन्तिम क्वाटरनरी, परागाणुस्तरिकी, पुरावनस्पतियाँ, पुराजलवायु, गढ़वाल हिमालय.

INTRODUCTION

DEORIA TAL is located in the temperate belt at an elevation of 2,727 m a.s.l., about 8 km east of Okhimath Town in district Chamoli between 75°5' Long. and 30°5' Lat. The lake is almost circular in outline and has a circumference of 150 m, having steep raised margin on eastern flank, devoid of any surrounding marsh or swampy ground (Fig. 1). The lake is encircled by high mountains covered with Oak forests. It is fed by subterranean water source and held sacred by local populace.

CLIMATE

The present climate of this region is temperate and is typical montane type with well defined rainy, winter and summer seasons. The maximum annual mean temperature ranges from 15°C to 25°C, but during winter it goes down to 5°C and occasionally even below 0°C, when extremely cold. The lake proper, i.e., Deoria Tal remains covered with a blanket of ice during the months of January and February though on the immediate lower hill slopes, snow fall is rare. Average annual rainfall is about 2,000 mm.

VEGETATION

The hill slopes around the lake are largely covered with Oak forests. *Quercus semecarpifolia* is the chief element, associated with *Rhododendron arboreum, Aesculus indica, Alnus nepalensis, Acer caesium, Fraxinus excelsior, Ulmus wallichiana, Myrsine africana, Salix elegans, Pyrus mallus,* etc. Other arboreals, such as *Myrica esculanta, Lyonia ovalifolia, Symplocos* and *Engelhardtia bellutianum* have sporadic distribution in these forests. Shrubby vegetation comprises *Berberis asiatica, B. chirta, Rosa moschata, Rubus ellipticus, Lonicera* spp., *Crataegus cranulata, Zanthoxylum alatum, Viburnum fruticosa,* etc.

The herbaceous vegetation in these forests is quite gregarious and is constituted of *Anaphalis adnata, Potentilla fulgens, Pedicularis* sp., *Berginia ligulata, Swertia chirta, Geranium nepalense, Agremonia* sp., *Aster peduncularis, Sedum trifidum, Saxifraga diversifolia*, etc. The narrow margin of the lake on the western flank has meagre marshy vegetation comprising mainly *Cyperus rotundus, Ammania baccifera, Eriocaulon* sp. However, many ferns viz., *Asplenium* sp., *Dryopteris* sp., *Adiantum* sp., *Polypodium* sp., often form gregarious patches inside the forest, preferring moist and damp situations.

The arboreals which are met with quite frequently in and around villages or settlements are *Ficus roxburghii, F. glomerata, Celtis australis, Grewia optiva, Boehmeria platyphylla, Cedrela toona, Citrus* sp.

Chirpine forests cover the lower hill slopes of the adjoining or surrounding mountain ranges which are almost devoid of any undergrowth.

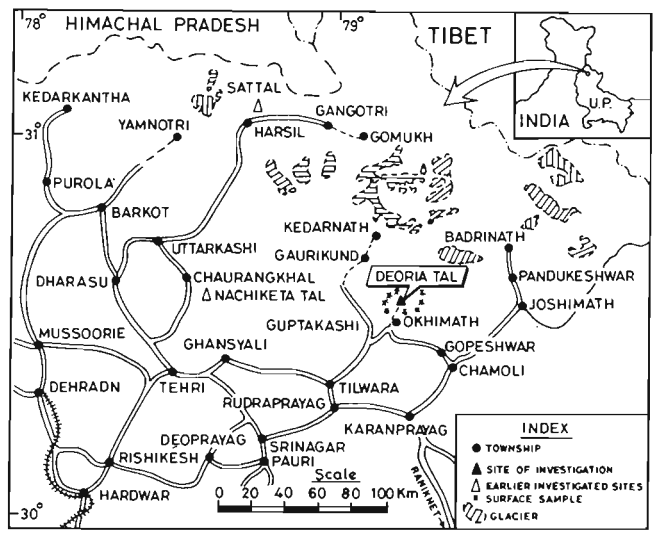

Fig. 1—Sketch Map of Garhwal showing the area of study.

MATERIAL AND METHODS

A 3 m deep trench was dug out very close to the selected eastern margin, and 60 samples were collected for pollen analysis. For modern pollen rain study, 8 surface samples (moss cushions) were also collected from the adjoining Oak forests.

The lithological succession in the trench did not exhibit any marked stratification and was composed of sandy-clay, clayey-sand, sand mixed with embedded charcoal pieces and pebbles. Lithological details are as under:

Depth (in cm)	*Lithology*
0-35	Sandy-clay with charcoal pieces and rootlets
35-65	Sand-clay with less charcoal pieces and rootlets
65-85	Sandy-clay with charcoal pieces
85-130	Sandy-clay with pebbles
130-205	Sandy-clay with charcoal pieces
205-225	Clay mixed with sand, charcoal pieces and pebbles
225-265	Clay mixed with sand and big stone pieces
265-300	Clay mixed with sand, charcoal, pebbles and big stone pieces

Retrieval of pollen/spores from the surface and profile samples has been done by standard procedure (Erdtman, 1943), using 10% aqueous KOH solution, 40% HF and acetolysis mixture (9:1, acetic anhydride and Conc. sulphuric acid). The pollen counts per sample range from 150-200 and the recovered taxa are categorized as trees, shrubs, herbs and ferns and are arranged in the same sequence in pollen diagram as well as pollen spectra.

RADIOCARBON DATES

Seven radiocarbon dates determined for the profile are as per detailed below:

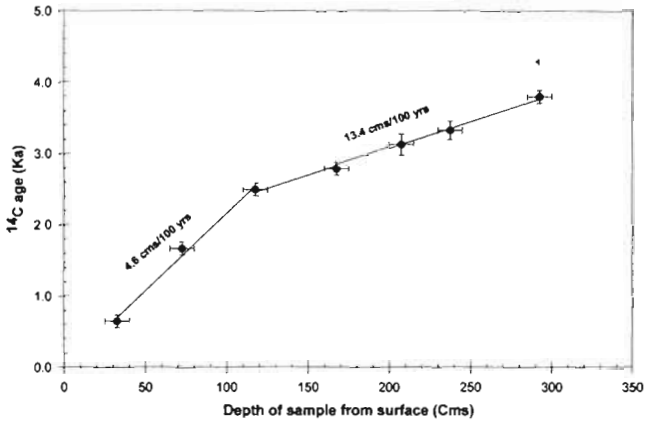

Fig. 2—Radiocarbon ages of sediment profile, Deoria Tal.

The rate of sedimentation as calibrated from radiocarbon dates is not uniform (Fig. 2). During the period of 3800±90 to 2510±90 yrs BP, covering a depth of 110-300 cm in the lithocolumn, the rate of sedimentation is 13·4 cm/100 years. The coarse sediment deposit during this interval demonstrates its quick deposition rate. This sedimentation rate gradually declines to 4·6 cm/100 yrs between 2510±90 to 650±90 yrs BP in the upper half (110-0 cm) of the profile.

MODERN POLLEN RAIN STUDY

To generate the needed data base for comparative modern pollen/vegetation relationship, eight surface samples (moss cushions) gathered from the temperate Oak forests in the vicinity of the lake site were pollen analysed. The pollen assemblage (Fig. 3) shows overall dominance of arboreals

Depth (in cm)	*Lithology*	*^{14}C Dates (yrs BP), $T_{1/2}$= 5730± 40*		*Calibrated ages (Stuiver & Reimer, 1993)*	*Calibrated age ranges*
25-40	Sandy-clay with charcoal pieces	BS-1180	650±90	608·5	670-547
65-80	Sandy-clay with charcoal pieces	BS-1170	1670±90	1525	685-1410
110-125	Sandy-clay	BS-1188	2510±90	2551·5	2745-2358
160-175	Sandy-clay with charcoal pieces	BS-1171	2790±90	2781	2918-2910
200-215	Clay mixed with sand,charcoal pieces and pebbles	BS-1172	3130±120	3308·5	3342-3275
230-245	Clay mixed with big stone pieces	BS-1173	3300±100	3465	3625-3359
285-300	Clay mixed with charcoal pieces	BS-1169	3800±90	4020	4149-3891

though with fluctuating frequencies and exhibits coherence with their actual composition in the existing forests. The major arboreal taxa are *Quercus* (15-30%), *Alnus*, *Rhododendron* (5-10% each) and *Betula* (3-10%). The high frequencies of encountered *Pinus* pollen ranging from 14-38% denote its drifted nature since the taxon in question does not grow in the proximity of the lake. However, good Chirpine forests are confined to the hill slopes adjacent to lake. Among the broad-leaved associates of *Quercus*; *Corylus* (5%), *Juglans* (3%) and *Myrica* (2%) remain under-represented as compared to their factual proportion in these forests which is attributed to their low pollen productivity and probably also for their poor preservation in the sediments. *Viburnum* (2-3%), Rosaceae and *Strobilanthes* (2% each) are prominent shrubby elements represented faithfully in the pollen spectra, whereas *Berberis*, Fabaceae and Oleaceae on the contrary are poorly represented regardless to their frequent occurrence in the forests. Many shrubby taxa viz., *Woodfordia fruticosa*, *Rubus ellipticus*, *Rosa moschata* and several others remain totally unrepresented. Their sparse distribution and low pollen production are probably important factors responsible for not making any impact on the local pollen rain.

Grasses, sedges and Cheno/Am are the major non-arboreal constituents of the pollen rain with representation corresponding more or less to their frequencies in the existing ground vegetation. *Potentilla*, *Saxifraga*, Ranunculaceae and Asteraceae despite their preponderance fail to demonstrate their true frequencies in the local vegetation as majority of these taxa are entomophilous. However, the high values of monolete as well as trilete fern spores portray true preponderance of ferns and some other pteridophytes inside the forests-particularly in damp and moist habitats.

DESCRIPTION OF POLLEN DIAGRAM

Pollen diagram from Deoria Tal (Fig. 4) has been divided into three well defined pollen zones from bottom upwards on the basis of fluctuations in the frequencies of some major arboreal and non-arboreal taxa. These pollen zones have been prefixed with "DT" after the name of the investigated site, i.e., Deoria Tal and are described below:

Pollen Zone DT-I (300-250 cm)-Quercus-Pinus-Rhododendron-Alnus-Ulmus assemblage

The bottom pollen zone is radiocarbon dated to 3,800±90 yrs BP (285-300 cm), depicting the dominance of *Quercus* (20-80%), followed by *Ulmus* (2-6%), *Alnus* (2-5%), *Betula* (1-5%), *Rhododendron* (1-4%), whereas, *Juglans* (1-5%), *Cupressus*, *Corylus*, *Carpinus*, *Acer*, *Salix* (2% each) are met

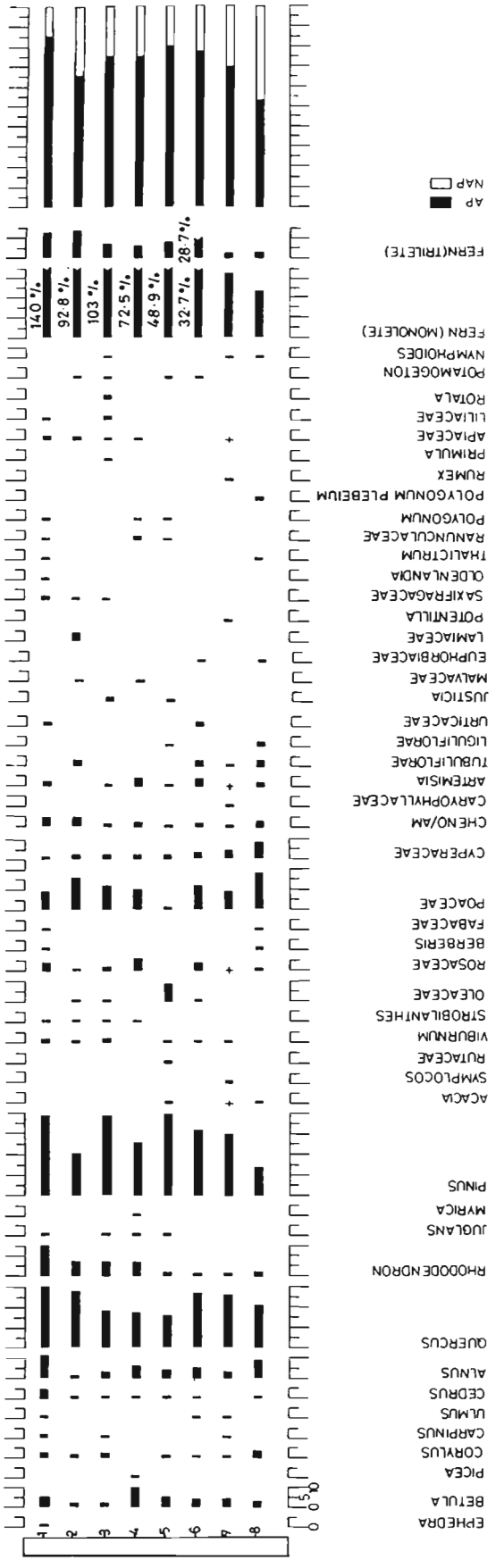

Fig. 3—Recent pollen spectra from Deoria Tal, Garhwal Himalaya.

with in comparatively low frequencies. Oleaceae, *Viburnum*, Rosaceae (2-5% each), Fabaceae and *Berberis* (1% each) are the represented components of shrubby vegetation. Poaceae (6-22%), Cyperaceae (7-11%), Cheno/Am (2-7%), *Artemisia* (4-5%) are present consistently besides, sporadic encounter of Tubuliflorae, Caryophyllaceae (2-4% each), Urticaceae (2-3%) and *Thalictrum* (2%).

Fern spores (monolete 20-26% and trilete 2-4%) showing more or less uniform values are encountered quite frequently throughout the zone.

The AP/NAP ratio reflects the closed nature of broad-leaved Oak forests in the region.

Pollen Zone DT-II (250-85 cm)-Quercus-Pinus-Alnus-Betula-Rosaceae-Sedges-assemblage

This zone is provided with four radiocarbon dates- 3,300±100 yrs BP (230-245 cm), 3,130±120 yrs BP (200-215 cm), 2,790±90 yrs BP (160-175 cm) and 2,510±90 yrs BP (110-125 cm). Almost similar vegetation pattern is revealed but with a decline in *Quercus* (7-15%) right from the inception of this pollen zone. *Pinus roxburghii* (8-12%), however, demonstrates somewhat fluctuatingly higher frequencies than witnessed in Pollen Zone DT-I. Other broad-leaved taxa viz., *Rhododendron* (1.5-2%) and *Ulmus* (1-2%) decline, whereas *Alnus* (2-8%), *Betula* (1·5-8%) and *Corylus* (2%) exhibit enhanced frequencies as compared to the preceding zone. *Juglans* disappears at the beginning of the zone but compensated by the first appearance of *Symplocos* (2%). However, *Salix, Carpinus, Ephedra* and Meliaceae do not exhibit any significant change in their frequencies and many shrubby elements viz., *Viburnum,* Rosaceae (1·5-3% each) and Oleaceae (1-4%) remain static.

Herbaceous vegetation is characterized by enhanced frequencies and consistent representation of Poaceae (30-50%), Cyperaceae (4-5%), Cheno/Am and Brassicaceae (1·5-10% each), associated with the first appearance of *Primula*, *Anagallis* and *Lonicera* (1% each). Fern spores have increased values than witnessed in the Pollen Zone DT-I.

The overall AP/NAP ratio depicts open type of forests in comparison to the preceding phase.

Pollen Zone DT-III (85-0 cm)-Quercus-Pinus-Alnus-Betula-Rosaceae-Grasses-*Sedges*-Cheno/Am assemblage

This pollen zone with two radiocarbon dates- 1,670±90 yrs BP (65-80 cm) and 650±90 yrs BP (25-40 cm) portrays improvement in the values of *Quercus* (10-25%), *Pinus roxburghii* (5-24%), *Betula* (2-8%) and *Corylus* (1·5-4%) on one hand and decline in *Acer* (1-7%). Sporadic reappearance of *Juglans* (2-3%) and better representation of shrubby elements such as *Viburnum* (2-5%), Rosaceae, Fabaceae (2-

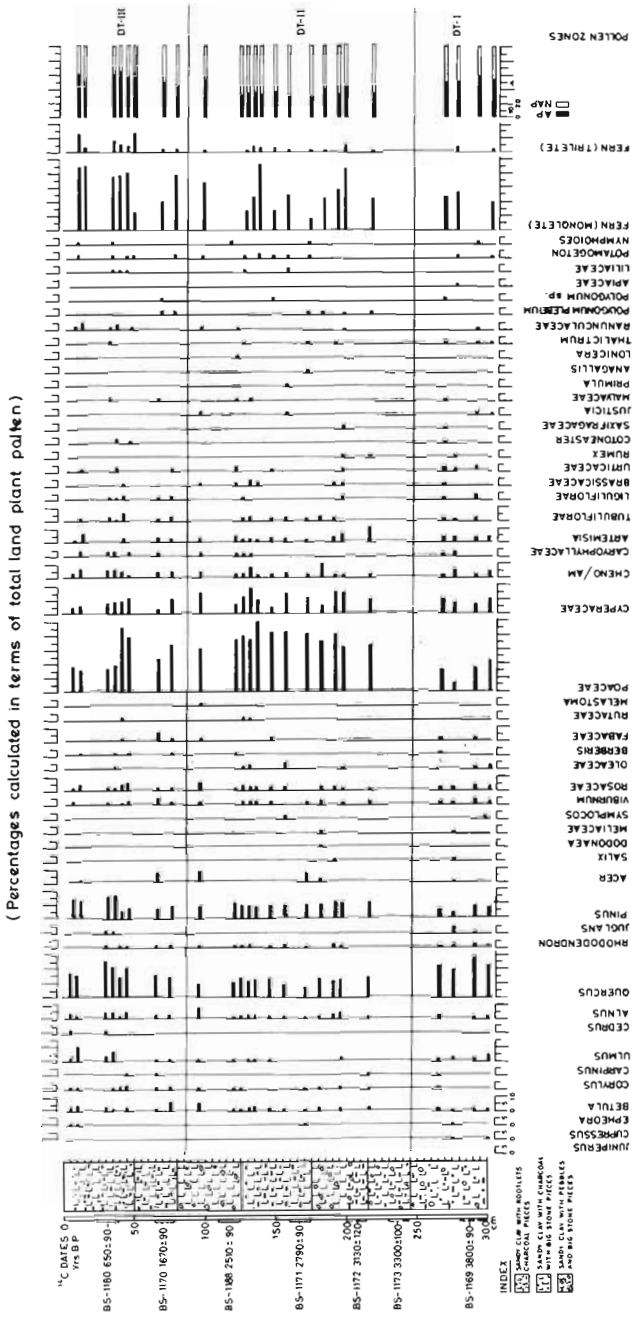

Fig. 4—Pollen diagram from Deoria Tal, Garhwal Himalaya.

7% each) and *Berberis* (2-3%) characterise this zone compared to the preceding zone.

Poaceae (17-47%) and Cyperaceae (3-13%) maintain higher frequencies though with a decline witnessed towards the top of the zone, whereas Cheno/Am (2-8%), *Artemisia* (3-7%), Caryophyllaceae (2-5%) providing non-arboreal coverage remain more or less unchanged. However, Tubuliflorae (1·5-7%), Ranunculaceae (2-5%) and Liguliflorae (2-3%) show improved frequencies and so the fern spores.

The AP/NAP ratio denotes the establishment of closed broad-leaved Oak forests once again.

VEGETATION AND CLIMATE

A good number of sedimentary profiles have so far been investigated from different regions of Western Himalaya and cover Kumaon (Vishnu-Mittre *et al.*, 1967; Gupta, 1977; Sharma, 1993; Chauhan & Sharma, 1996), Himachal Pradesh (Sharma, 1985b; Sharma & Chauhan, 1988; Sharma & Singh, 1974a, b; Bhattacharyya, 1988) and Kashmir (Gupta *et al.*, 1984; Sharma & Gupta, 1985; Sharma *et al.*, 1985). Consequently, a fairly reliable reconstructed palaeovegetation scenario and corresponding climatic events inferred for the Quaternary Period has emerged for different sectors across the Himalayan transact.

But for the four profiles investigated recently from the temperate Nachiketa Tal and subalpine Chharaka Tal lakes in Uttarkashi District (Sharma & Gupta, 1995; Chauhan *et al.*, 1996), Deoria Tal-Profile 2 (Sharma & Gupta, 1997) and Dewar Tal (Chauhan & Sharma, 2000) in Chamoli District, not much palynostratigraphical data is available from Garhwal region, i.e., the Himalayan sector lying between Himachal Pradesh in the west and Kumaon Himalaya in the east.

Pollen analysis of 3 m long profile-I from Deoria Tal, located in the temperate altitudinal range covers the vegetation history of only past 4,000 years. Between 4,000-3,200 yrs BP, existence of temperate Oak forests is indicated by the presence *Quercus, Ulmus, Alnus, Rhododendron, Betula* and *Juglans* with shrubby elements-*Viburnum*, Rosaceae, Fabaceae, etc. Cool and moist climate is inferred during this phase from the overall floristic composition. The encounter of *Pinus roxburghii* pollen in appreciable numbers when it does not grow at this elevation today is transported from the lower mountain slopes where good Chirpine forests actually exist. Presence of fern and other pteridophytic spores indicates the prevalence of moist climatic condition in the area.

During the period 3,200 to 1,700 yrs BP, the Oak forests though continued to flourish in the region, they became less dense and more or less open type as evident by the reduced frequencies of not only *Quercus* but also its associates-*Rhododendron, Ulmus*, and disappearance of *Juglans*. However, other broad-leaved taxa such as *Alnus*, *Betula* together with *Viburnum*, Rosaceae and Fabaceae do not show any significant change in their representation. This change in the vegetation mosaic took place perhaps in response to the reduced precipitation. Simultaneous expansion of Chirpine forests coupled with improvement in the ground coverage by grasses and sedges is a supporting evidence to infer that the climate in the region turned a little drier. Decline in Oak can partly be attributed probably to the advent of human activities in the area. However, clearance of forests for cultivation or selective felling of this important forest ingredient by thin local population in this interior region of Himalaya can not register the marked impact witnessed through the change in the frequencies of *Quercus* and its other associates. The recovery of charcoal pieces in the lake sediments at this elevation and enhanced frequencies of certain ruderal plants taxa such as Brassicaceae, Chenopodiaceae/Amaranthaceae, *Artemisia*, Asteraceae do indicate the possible anthropogenic pressure on the natural vegetation.

During the subsequent phase covering the last 1,700 years, the same vegetation pattern continued in the region, but with a noticeable expansion of Oak forests together with its other broad-leaved associates viz., *Alnus*, *Rhododendron*, *Ulmus*, *Betula*, *Corylus* which too became more prominent compared to their representation in the preceding phase. The emerged vegetation composition signifies amelioration in the climate which turned warmer and more moist.

Acknowledgements—*Authors are grateful to Prof Anshu K Sinha, Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing necessary facilities and constant encouragement to accomplish this work.*

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