Journal of The Palaeontological Society of India
Vol. 46, 2001, pp. 51-58

LATE HOLOCENE VEGETATION AND CLIMATE OF KUPUP (SIKKIM), EASTERN HIMALAYA, INDIA

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ABSTRACT

Pollen analysis of 120 cm deep maiden sedimentary profile procured from Kupup Lake in Sikkim Himalaya, situated in the alpine zone at 4,000 m elevation provided with three 14C dates : 800±90 yrs BP (10-15 cm), 200± 90 yrs BP (15-25 cm) and 1630±100 yrs BP (90-100 cm), has revealed the vegetation dating back to ca. 2000 yrs in the region. It comprised mainly sedges, grasses, Apiaceae, Asteraceae associated with *Pinus, Abies, Tsuga, Quercus, Betula, Alnus, Rhododendron, Viburnum,* etc. The reconstructed palaeovegetation is characteristic for the alpine zone and not much different from what could be seen today. The overall vegetation composition signifies that cold and moist climate prevailed during 2000-1800 yrs BP and most probably beyond. However, between 1800-1450 yrs BP, a decline in the frequencies of some broad-leaved taxa, viz., *Betula, Alnus, Rhododendron,* etc. with corresponding improvement in sedges, grasses and other herbaceous elements is registered, indicating a short spell of slightly drier conditions probably as a consequence of the reduction in the precipitation. Soon after, the climate was restored to earlier cold and moist conditions during 1450-450 yrs BP. In fact, this restoration is witnessed by better representation of broad-leaved taxa. Such an amelioration in climate in the Himalayan alpine zone corresponds satisfactorily to the global Medieval Warm Period which is believed to have occurred during 700 AD-1200 AD. Significant sudden reduction of arboreals with simultaneous rise in sedges, grasses, Chenopodiaceae/Amaranthaceae, Ranunculaceae, etc. between 450 and 200 yrs BP, i.e. 1500 AD and 1750 AD is indicative of a deterioration in climate for a short period and can be attributed probably to the impact of Little Ice Age recorded for the period 1450 AD-850 AD. However, the subsequent phase encompassing the last 200 years is well demonstrated by expansion of *Quercus, Betula, Alnus* and Rosaceae under the improved climate, i.e. cold and moist conditions characteristic of the present alpine zone in the Eastern Himalayan Sector.

Key words: Pollen analysis, Eastern Himalaya (Sikkim), Late Holocene, vegetation and climate.

INTRODUCTION

Palynostratigraphical investigations carried out for reconstructing the vegetation succession to deduce the climate during the Quaternary Period have so far covered the subtropical and temperate belts of Western Himalaya (Vishnu-Mittre, Gupta and Robert, 1967; Sharma and Singh, 1974a, 1974b; Sharma and Chauhan, 1988; Sharma, 1993; Chauhan and Sharma, 1996; Kotlia, Bhalla, Sharma, Rajagopalan, Ramesh, Chauhan, Mathur, Bhandari and Chacko, 1997), Central Himalaya (Vishnu-Mittre and Sharma, 1984) and Eastern Himalaya (Bhattacharya and Chanda, 1986; D' Costa and Mukherjee, 1986; Sharma and Chauhan, 1994; Chauhan and Sharma, 1996; Sharma, *in press*). However, the alpine region which is very sensitive to the changing climatic scenario, has not received adequate attention, except for the sporadic information available from the Western Himalaya (Bhattacharyya, 1988, 1989). Pollen analysis of glacial sediments above the tree limit or from the alpine zone has not so far attempted from the Eastern Himalaya.

The present paper deals with the pollen data ever generated from the alpine zone from the Eastern Himalaya to understand the vegetation changes and climatic fluctuations in the past through investigated Kupup sedimentary profile in Sikkim Himalaya.

Lake Kupup in Sikkim lies approximately 40 km east of Gangtok at an elevation of 4000 m a.s.l. (fig. 1). It is a big clean water expanse almost circular in outline, surrounded by mountain ridges having gentle slopes which remain covered with thick sheet of ice for the major part of the year. The lake is fed by melting ice and subterranean water as it does not receive any streams or rivulets. The lake is devoid of any swamp or marshy margin owing to very poor seasonal vegetation cover. The gorges and valleys seen around the lake do have huge moraine deposits as a result of intense glaciofluvial activity in the area.

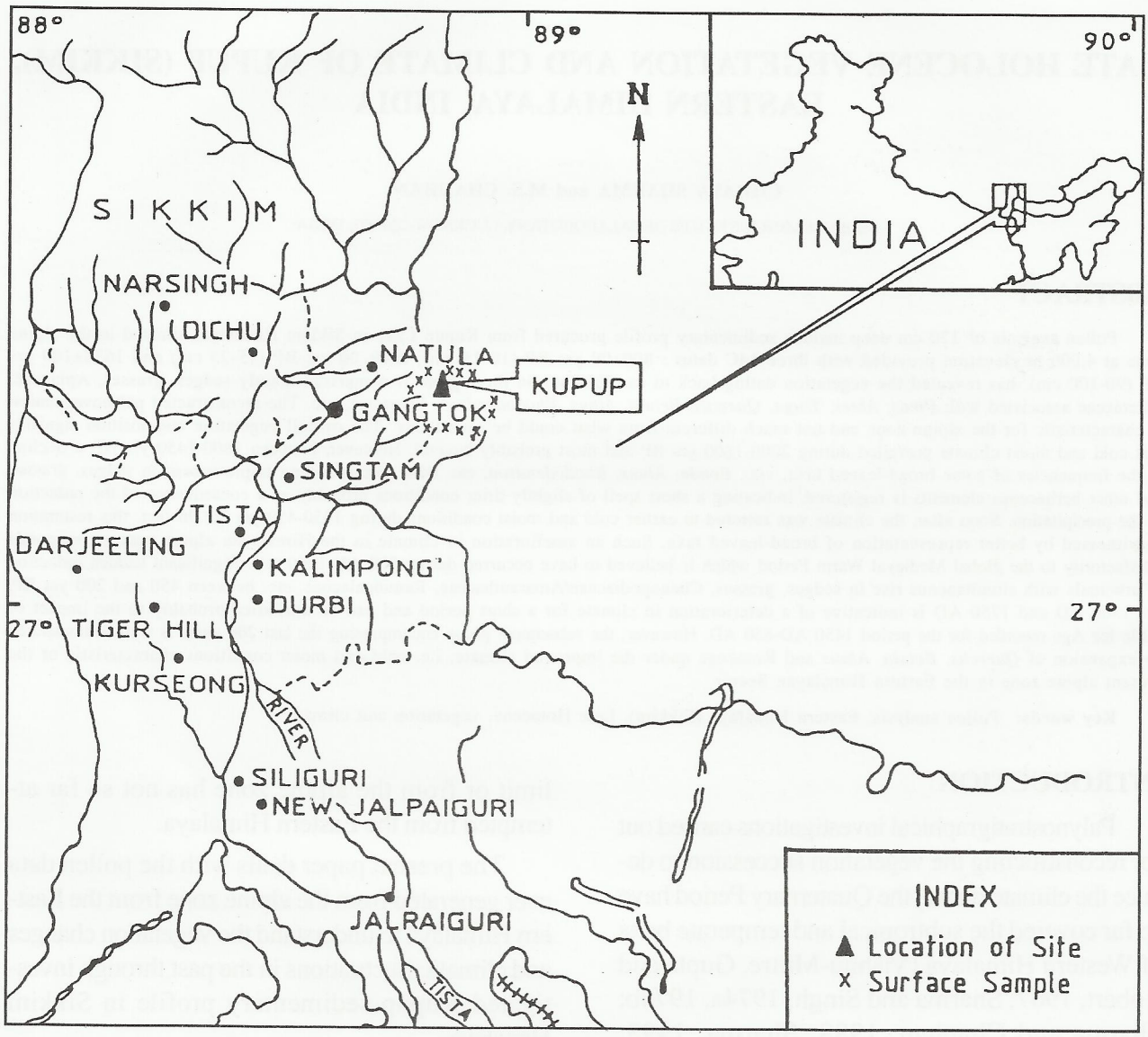

Fig. 1. Map showing the location of the lake site and surface samples.

Climatic and other meteorological records for the Kupup region are not available. The general observations made in this regard indicate that the lake is fed by the melting ice during the major part of the year, besides rains during May to September. However, Sikkim has an annual rainfall which varies from 1300 mm to 4300 mm (between 300 m - 2000 m elevation) and 60-75% of this rain falls during the months of June-September.

VEGETATION

The ground cover in the vicinity of Kupup Lake is composed of characteristic alpine scrubby vegetation which for the major part of the year remains covered by snow. During summer months when the snow melts, the herbaceous vegetation comes up luxuriantly comprising predominantly *Saxifraga fimbristylis, Polygonum viviparum, Androsace lanuginosa, Caltha palustirs, Meconopsis*

aculeata, Primula sp., *Pedicularis mollis, Thalictrum alpinum, T. elegans, Sedum* sp., *Aster* spp., *Saussaurea* sp., *Arneria* sp., *Rheum* sp., *Clematis montana, Ranunculus adoxifolius, Gentiana* spp., etc. Gregarious patches of *Polygonum, Potentilla, Primula*, etc. are seen mostly in the moist depressions and along the trickling water courses. Some arboreals such as *Rhododendron nivale, R. anthopogon, R. thomosonii, Salix sikkimensis, Betula utilis, Cotoneaster* spp., etc. exhibiting stunted growth are scattered. However, *Juniperus squamosa* and *Ephedra saxatalis* grow frequently on certain dry mountain slopes in the region.

STRATIGRAPHY AND RADIOCARBON DATES

A total number of 24 samples were collected from 120 cm deep sedimentary profile with the help of Hiller's peat auger at an interval of 5 cm each. Material for radiocarbon dating was also taken out at three different horizons of the core. Deeper coring operation around this high altitude montane region is not feasible owing to hard stratum beneath.

Lithostratigraphically, the dug out core comprised mainly peat mixed with clay and sand and apparently had no marked delineation.

Three readiocarbon dates determined for the investigated profile are as under:

Based on the available radiocarbon dates, the rate of sedimentation has been calibrated to ca. 7 cm/100 yrs for the profile (fig. 2).

Depth No.	Lithology	Radiocarbon date	Laboratory reference
0-15 cm	Peat mixed with clay	880 ± 90 yrs BP	BS-1135
15-25 cm	-do-	200 ± 90 yrs BP	BS-1136
90-100 cm	Peat mixed with clay and sand	1650 ± 100 yrs BP	BS-1134

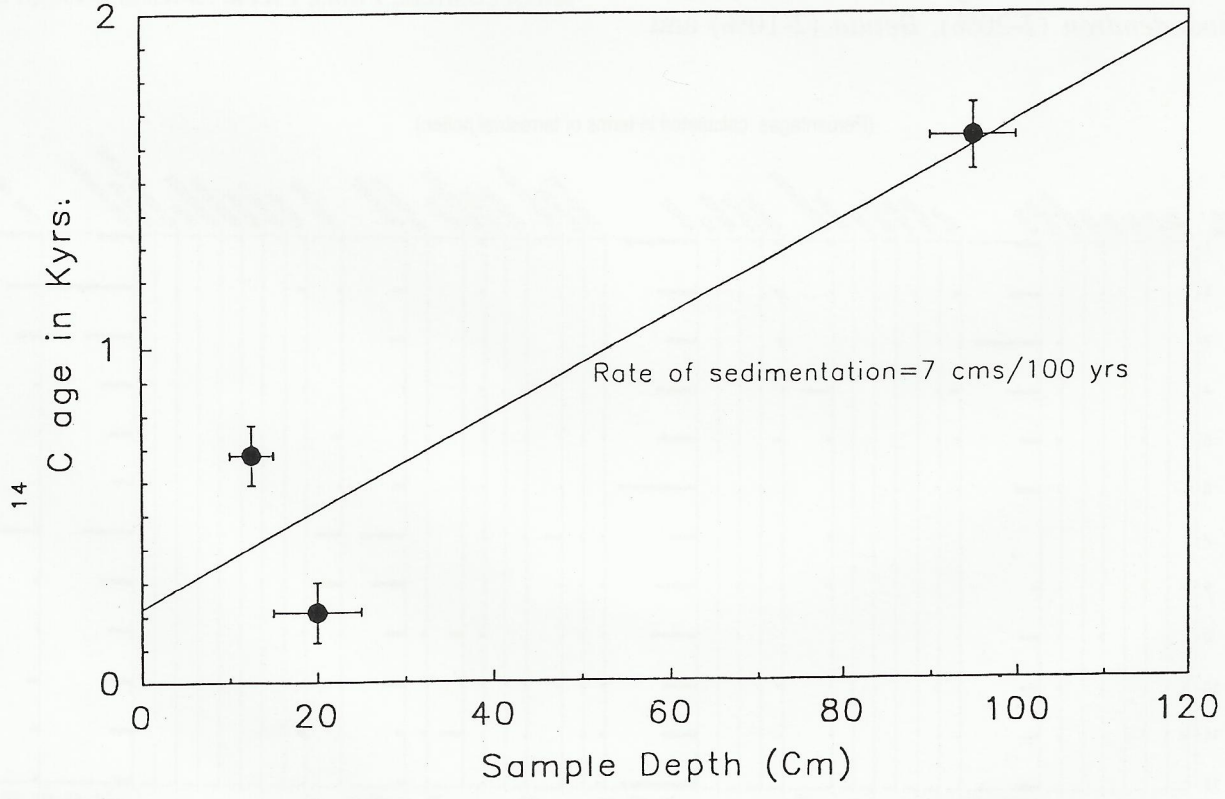

Fig. 2. Plot of radiocarbon dates verses depth, Kupup Lake profile.

POLLEN ANALYSIS

Extraction of pollen/spores from the surface and core samples has been done through conventional technique of acetolysis (Erdtman, 1943, 1969). Pollen counts per sample vary from 150-300 both for surface as well as profile sediments. Frequency percentages of recovered pollen/spores have been calibrated in terms of total terrestrial pollen and the encountered taxa are grouped as trees, shrubs, herbs and ferns arranged in the constructed pollen diagram in the same sequence.

MODERN POLLEN / VEGEATATION RELATIONSHIP

To understand the modern pollen/vegetation relationship in the region, 12 surface samples picked up at 50 m interval from the vicinity of Kupup Lake were pollen analysed (fig.3). The study has shown the dominance of non-arboreals over arboreals. Among the arboreals, *Alnus* (10-45%) is recorded in high values. Others such as *Rhododendron* (2-20%), *Betula* (2-10%) and Rosaceae (2-6%) are recovered in moderate frequencies, whereas *Carpinus* (2-5%), *Quercus* (1-3%), *Corylus* (2%), *Ulmus* (1%) are met with sporadically.

The non-arboreals, Poaceae 20-60% followed by Tubuliflorae (2-30%), Liguliflorae (2-20%) are represented in high values. Likewise, Apiaceae (2-15%), Ranunculaceae (1-6%), Cyperaceae, *Artemisia* (2-4% each) are also encountered in good frequencies, whereas *Polygonum, Impatiens*, Cheno/Ams, Urticaceae are extremely low and sporadic. Fern spores (monolete 20-60% and trilete 5-35%) are encountered in abundance.

Thus, the pollen spectra have truly portrayed open type of vegetation by way of low frequencies of tree taxa as reflected by the sporadic presence of *Quercus, Corylus, Betula, Carpinus* and *Ulmus*, except for *Alnus* and *Rhododendron* which are represented in accordance to their presence in the regional floristics. The recovery of pollen of conifers, *Pinus, Picea, Abies* and *Tsuga* en-

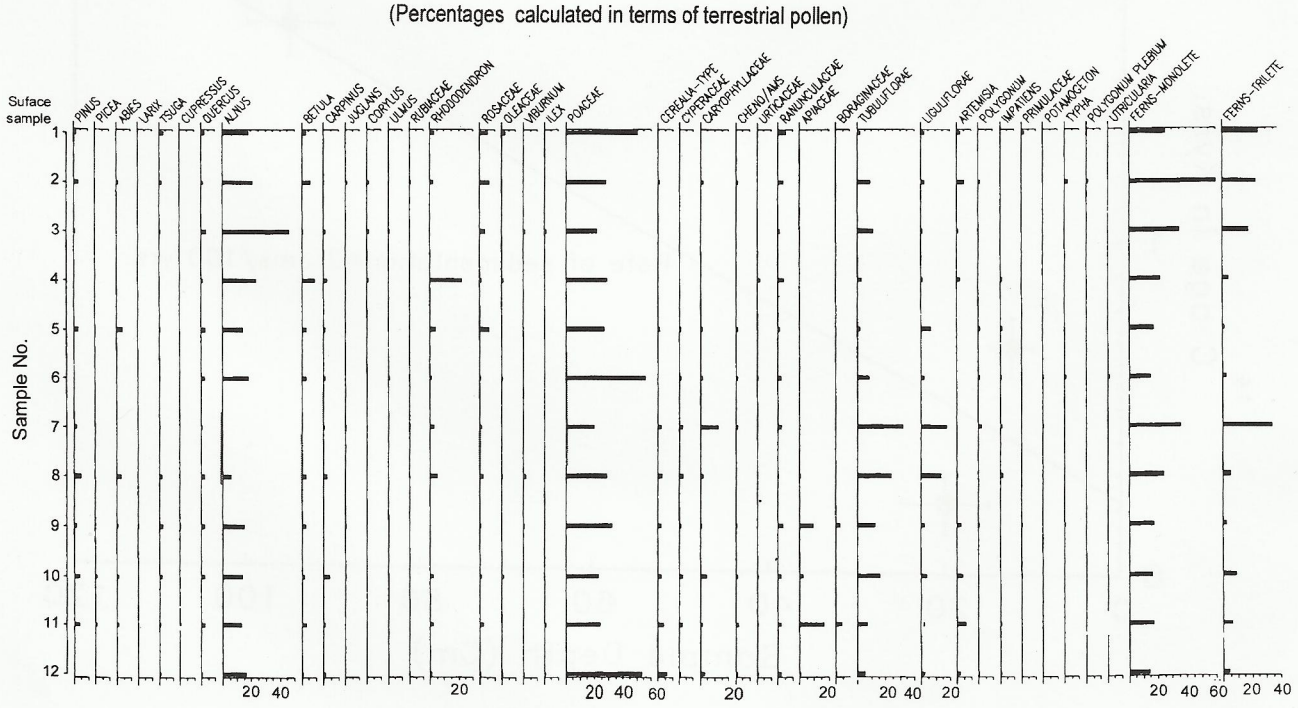

Fig. 3. Recent Pollen spectra from Kupup area, Eastern Himalaya.

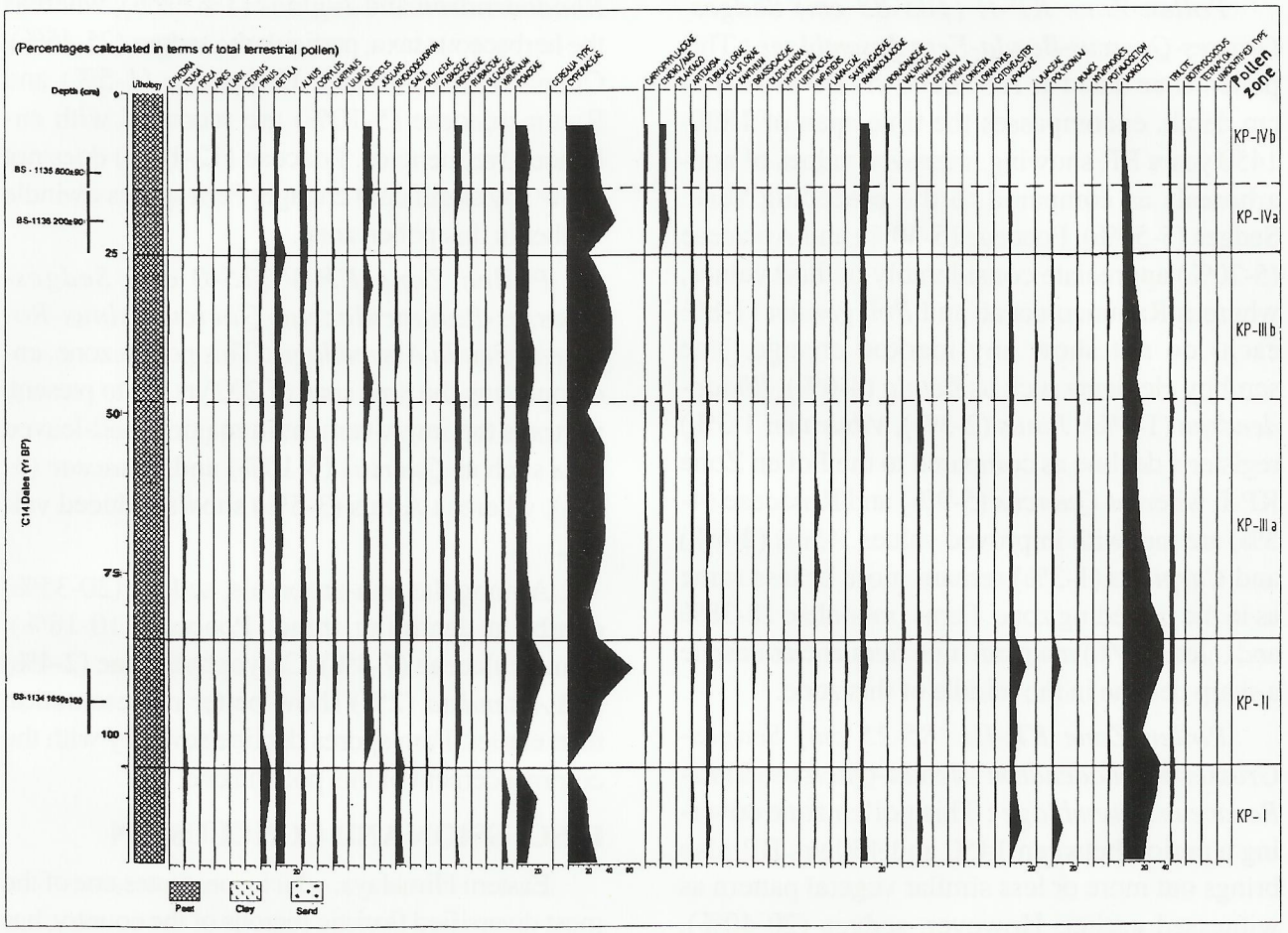

Fig. 4. Pollen diagram from Kupup Lake.

visages their transportation from the surrounding mountains.

The good representation of Poaceae, Asteraceae, Apiaceae, *Artemisia* and *Polygonum* shows the close coherence with their composition in the ground flora. The excessively high values of ferns denote their profuse growth in damp and moist habitats.

DESCRIPTION OF POLLEN DIAGRAM

Based on the fluctuations seen in the representation of prominent arboreals and non-arboreals, the pollen diagram is divided into five pollen assemblage zones : KP-I, KP-II, KP-III, KP-IV & KP-V, starting from bottom upwards. Each pollen zone is prefixed by the abbreviation KP signifying the investigated site-Kupup (fig. 4).

Pollen Zone KP-I (120-105 cm) Sedges-Grasses-Betula-Rhododendron Fern Assemblage: Bottom pollen zone, covering a time span of *ca.* 2000-1800 yrs BP, reveals the dominance of non-arboreals over arboreals. Cyperaceae (sedges 18-28%) followed by Poaceae (grasses 9-19%), Apiaceae (6-10%), *Polygonum* (2-9%) and Ranunculaceae are the major components of the ground vegetation. The arboreals, *Betula* (8-9%), *Rhododendron* (6-8%), *Pinus* (5-9%), *Alnus, Carpinus* (2-4% each) and *Viburnum* (2-9%) are recorded in good values, whereas *Corylus*, *Quercus*, *Ulmus* and *Juglans* (1% each) are sporadic. Fern spores (monolete 3-20% and trilete 2-4%) are well represented.

Pollen Zone KP-II (105-85 cm) Sedges-Grasses-Quercus-Betula-Fern Assemblage : This pollen zone dated at 1650±100 yrs BP at 90-100 cm depth, encompasses the time span of 1800-1450 years BP, showing improved values of non-arboreals as compared to the preceding zone. Sedges (5-50%), Poaceae (5-30%) and Apiaceae (5-20%) appreciate considerably in their values, whereas Ranunculaceae and *Polygonum* (1-8% each) do not show any marked change. The scrubby elements such as *Betula* (4-6%), *Rhododendron* (1-4%), *Pinus* (2-3%), *Viburnum* 1-3%) register a decline as compared to the Pollen Zone KP-I, whereas *Quercus* (5-9%) and Rosaceae (4-5%) are met with improved values. *Alnus* (2-4%) and *Carpinus* (1-3%) remain more or less same as in the preceding zone. Ferns (monolete 18-38% and trilete 2-4%) maintain high frequencies despite a sharp decline in the middle of this zone.

Pollen Zone KP-III (85-25 cm) Sedges-Grasses-Rhododendron -Betula-Quercus-Alnus-Rosaceae Assemblage : This pollen zone covering a period between 1450 and 450 yrs BP, also brings out more or less similar vegetal pattern as witnessed earlier. However, sedges (20-40%), grasses (10-20%), Apiaceae (2-5%), *Artemisia* (1-4%) and *Polygonum* (3%) are recorded in reduced frequencies. The arboreals, *Betula* (5-10%), *Alnus* (4-8%), *Rhododendron* and *Quercus* (2-11% each) have increased values. *Juglans* (1-2%) reappears in this pollen zone, whereas shrubby elements, Rosaceae (2-4%), Fabaceae and *Viburnum* (1-4%) each) also become prominent. Fern spores (monolete 10-50% and trilete 2-4%) decline sharply with the commencement of this pollen zone.

Pollen Zone KP-IV (25-15 cm) Sedges-Grasses-Ranunculaceae-Quercus-Betula-Alnus-Cheno-/Ams-Ranunculaceae Assemblage : This pollen zone, with radiocarbon date of BS-1135 200±90 yrs BP and covering a time period of 450-200 yrs BP, portrays a sharp decline in the scrubby elements such as *Betula* (10-2%), Alnus (6-4%), *Rhododendron* and *Juglans* (1% each), whereas the herbaceous taxa, particularly, sedges (25-45%), Cheno/Ams (2-10%(), Urticaceae (1-5%) and Ranunculaceae (5-10%) are recorded with enhanced frequencies. Poaceae (12-16%) does not show any significant change. Fern spores dwindle further in this pollen zone.

Pollen Zone KP-V (15-0 cm) Sedges-Grasses-Ranunculaceae-Quercus-Alnus-Rosaceae-Betula Assemblage : This pollen zone, encompassing the time span of 200 yrs BP to present, portrays the improvement in major broad-leaved taxa such as *Quercus* (5-10%) and *Rosaceae* (3-6%), whereas Alnus (3-5%) shows reduced values.

Among the non-arboreals, sedges (20-35%) exhibit a declining trend. Poaceae (10-18%), Ranunculaceae (7-8%), Caryophyllaceae (2-4%) and *Artemisia* (2%) show better representation than earlier. Fern spores decline severely with the commencement of this pollen zone.

DISCUSSION AND CONCLUSION

Eastern Himalaya, which constitutes one of the most diversified floristic regions of the country, has not yet received due attention pertaining to palaeovegetational changes and palaeoclimiatic fluctuations during the Quaternary Period. A few sedimentary profiles have so far been investigated from the temperate lakes of Darjeeling (D'Costa and Mukherjee, 1986; Sharma and Chauhan, 1994; Chauhan and Sharma, 1996) and Sikkim (Bhattacharya and Chanda, 1986; Sharma, *in press*) and a broader picture of the changing vegetation pattern has been built up. However, no palynological studies have been carried out from the glacial sediments above tree limit or alpine region which has a great potential to unravel the climatic oscillations at shorter intervals.

In the present paper, an attempt has been made to decipher the changes in the vegetation pattern around the alpine lake Kupup and their relation to climatic fluctuations during late Holocene

epoch through palynostratigraphical proxy data generated from the lacustrine sediments. Although the 120 cm deep core from Kupup Lake has a maximum date of 1650±100 yrs BP, it could be possible to extrapolate the date for the beginning of the sequence to ca. 2000 yrs BP. The vegetation sequence has portrayed that during 2000 to 1800 yrs BP this region had alpine scrub vegetation in which the herbs such as sedges, grasses, Apiaceae along with thermophilous broad-leaved taxa such as *Betula, Alnus, Rhododendron* and *Vibrunum* were the major components. The other taxa, viz., *Carpinus, Corylus, Quercus* were meagerly distributed. The vegetation composition, in general, reflects that the region was probably under the influence of warm and moist climate during this phase. The fair amount of pollen of temperate conifers, *Pinus, Tsuga* and *Larix* could be indicative of extension of temperate belt towards the higher elevations in response to prevailing favourable climatic regime in the region.

Around 1800 to 1450 yrs BP, the alpine scrub vegetation continued to exist in the region without undergoing major alterations in the floristic composition. However, the broad-leaved taxa such as *Betula, Alnus, Rhododendron* had declined, except for *Quercus* and Rosaceae which had improved a little; whereas a corresponding expansion of the herbaceous taxa, sedges, grasses, Tubuliflorae, Apiaceae had also occurred. The overall fluctuations in the representation of these prominent taxa during this period point to the deterioration in climate which was most probably cold and dry. Besides, the reduced frequencies of conifers, viz., *Pinus, Larix,* and *Tsuga* also suggest that the tree line might have been distantly located under the effect of this cold climate.

Thereafter, during 1450 to 450 yrs BP, the climate once again turned to warm and moist as indicated by the substantial expansion of thermophilous broad-leaved small trees or scrubs, viz., *Betula, Alnus, Quercus, Rhododendron* and *Juglans* and a contemporary decline in the ground cover. This phase of climatic amelioration coincides chronologically with the period of medieval warming which has been recorded from 700 AD to 1200 AD as an important global feature.

Around 450 to 200 yrs BP, i.e. 1550 AD to 1750 AD, the broad-leaved scrubby taxa such as *Betula, Quercus* and *Rhododendron* declined. Likewise, the herbaceous complex also became less diversified than earlier, except for the slight improvement in sedges, Cheno/Ams, Ranunculaceae, etc. In general, the poor vegetation cover during this period implies the deterioration of climate which most probably became colder and drier than today's. Under the influence of such a harsh climatic regime, the mountain glacier might have also descended towards the lower elevations.

During 200 yrs BP onwards, the climate improved which favoured the expansion of the broad-leaved scrubs, *Betula, Quercus*, Rosaceae, *Salix* and conifers, e.g. *Abies*. The decline in grasses and sedges towards the termination of this phase also indicates that the climate became less drier and colder than in the preceding phase.

ACKNOWLEDGEMENTS

The senior author is grateful to the Department of Science and Technology, New Delhi for sponsoring the project No.Es/63/028/86, under which the present work on Eastern Himalaya (Darjeeling and Sikkim) was undertaken. Thanks are also due to Dr. G. Rajagopalan of the Institute for providing ^{14}C dates for this communication.

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Manuscript Accepted April 2001