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Late Holocene vegetation and climate in Dewar Tal area, Inner Lesser Garhwal Himalaya

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ABSTRACT

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Pollen analysis of 1·8 m deep sedimentary profile from Dewar Tal situated in the subtropical belt of Garhwal Himalaya has revealed that between 2,500 to 2,300 years BP, open mixed chirpine (*Pinus roxburghii*) and oak (*Quercus*) forests coexisted in the region, the former inhabiting sunny hill slopes and the latter occupying moist valleys under cool and dry climate. Subsequently, between 2,300 to 2,000 years BP these forests expanded in response to the amelioration in climate which probably turned warm and moist. Thereafter, between 2,000 to 1,400 years BP, the climatic condition deteriorated as witnessed by sudden decline in prominent arboreals like chirpine and oak, besides simultaneous improvement in grasses as well as other herbaceous elements. During the period 1,400 to 400 years BP, maximum development of oak forests indicates enhancement in the precipitation, resulting in the onset of warm and moist climate in the region. The latter part of this phase coincides closely with European Medieval Warm Period or Little Climatic Optimum of America. The constructed pollen diagram demonstrates that since 400 years BP (1,550 A.D.) cool and dry climate was restored as evidenced by gradual decline in mixed oak forest along with simultaneous expansion of chirpine forest in the region.

Key-words—Late Holocene, Palaeofloristics, Palaeoclimate, Garhwal Himalaya.

अन्तर्वर्ती लघु गढ़वाल हिमालय के देवार ताल क्षेत्र की अन्तिम होलोसीन वनस्पतियाँ एवं जलवायु

मोहन सिंह चौहान एवं छाया शर्मा

सारांश

गढ़वाल हिमालय की उपोष्णकटिबन्धीय बेल्ट में स्थित देवार ताल नामक स्थान से प्राप्त एक 1·8 मीटर गहरी अवसादी परिच्छेदिका के परागाणविक विश्लेषण से प्रदर्शित होता है कि 2,500 से 3,000 वर्ष पूर्व के मध्य इस क्षेत्र में विवृत सम्मिश्र चीड़ (*पाइनस रॉक्सबर्गाई*) एवं ओक (क्वर्कस) वृक्ष एक साथ पाए जाते थे. चीड़ के वृक्ष प्रकाश युक्त पहाड़ी ढलानों पर तथा ओक के वृक्ष शीत एवं शुष्क जलवायु में नम घाटियों में पाए जाते थे. कालान्तर में 2,300 से 2,000 वर्ष पूर्व के मध्य ये वृक्ष जलवायु में सुधार के कारण फैलते चले गए. इस समय सम्भवतः जलवायु उष्ण एवं नम हो गयी थी. इसके पश्चात 2,000 से 1,400 वर्ष पूर्व के मध्य जलवायुविक स्थितियाँ खराब होने लगीं, जिसके प्रमाण तत्समय घास तथा अन्य शाकीय तत्वों में वृद्धि के अतिरिक्त चीड़ एवं ओक जैसे महत्त्वपूर्ण वृक्षीयों में हुई अचानक गिरावट से देखे जा सकते हैं. 1,400 से 400 वर्ष पूर्व के दौरान ओक वनों में हुए अधिकतम विकास से अवक्षेपण में वृद्धि संकेतित होती है, जिसके परिणामस्वरूप क्षेत्र में उष्ण एवं नम जलवायु का आरम्भ हुआ. इस प्रावस्था का अग्रवर्ती भाग यूरोपीय मध्यकालीन उष्ण अवधि अथवा अमरीका के लिटिल क्लाइमेट ऑप्टिमम से गहन रूप से सम्पाती है. निर्मित किए गए परागकण आरेख से प्रदर्शित होता है कि 400 वर्ष पूर्व (सन् 1,550 ई.) से इस क्षेत्र में शीत एवं शुष्क जलवायु विद्यमान थी, जिसके प्रमाण इस क्षेत्र में तत्समय चीड़ वनों के विस्तार तथा ओक वनों में शनैः-शनैः ह्रास में देखे जा सकते हैं.

संकेत शब्द—अन्तिम होलोसीन, पुरावनस्पतिजातविज्ञान, पुराजलवायु, गढ़वाल हिमालय.

INTRODUCTION

Palaeofloristic and palaeoclimatic studies carried out earlier for the temperate and alpine floristic belts of the Garhwal Himalaya (Sharma & Gupta, 1995, 1997; Chauhan, *et al.*, 1997; Bhattacharyya & Chauhan, 1997; Sharma *et al.*, 2000) are inadequate to permit satisfactory reconstruction of vegetational succession and corresponding climatic changes in the Garhwal Himalayan region during the Quaternary Period. The present communication is one more contribution for deciphering palaeovegetation succession and corresponding climate during Holocene in the region and, if possible, to interpret the impact of anthropogenic activity from the generated data through the pollen analysed sedimentary core from Dewar Tal situated in the Inner Lesser Himalaya in the Garhwal region.

Dewar Tal (30° N Lat. & 79° E Long.) is an ancient lake basin, which lies about 7 km east of Gopeshwar township (district Chamoli) at an altitude of 1727 m a.s.l. The lake basin proper is an open swampy flat ground encircled by high mountains (Fig. 1). In fact, the open land is highly water-logged and is under intensive paddy cultivation. This swamp is fed by subterranean water and also by the stream, which flows close to it. Dewar Tal is delimited in the south by the river Alaknanda.

CLIMATE

Dewar Tal area has moderate subtropical to temperate climate characterised by warm summers and cold winters. Average minimum and maximum mean annual temperatures are 15°C and 24°C respectively. During extreme cold January and February months the temperature is as low as 5°C. The area seldom experiences snowfall during late winters. Heavy rains are quite frequent during the months of July and August and for Gopeshwar Town the recorded annual rainfall is about 2000 mm.

VEGETATION

The sunny side of the hill slope around the swampy lake basin has open pure chirpine forest along with oak patches confined mostly to the shady mountain slopes as well as the moist valleys. The oak forest components are *Quercus dilatata* and *Q. leucotrichophora*, while associated arboreals include *Rhododendron arboreum*, *Lyonia ovalifolia*, *Myrica esculanta*, *Myrsine africana*, *Pyrus mallus*, *Cotoneaster bacillaris*, *Litsea umbrosa*, etc. Shrubby elements in the open forest patches are *Berberis chirta*, *Deutzia corymbosa*, *Elaeagnus umbellata*, *Pyracanthus crenulata*, *Girardiana palmata*, *Principia utitis* and *Rubus paniculata* along with some climbers like *Hydrangea anomala* and *Hedera nepalensis*.

The herbaceous ground vegetation of these forests comprises mainly *Rumex hastatus*, *Dicliptera roxburghii*, *Reinwardtia indica*, *Tridax incumbens*, *Cynoglossum* spp., *Thalictrum foliosum*, *Seigesbeckia orientalis*, *Anagallis arvensis*, *Micromeria biflora*, *Nepeta* spp., *Artemisia parviflora*, etc.

Commonly seen plants around the cultivated land are *Ficus roxburghii*, *F. glomerata*, *Celtis australis*, *Grewia optiva*, *Boehmeria platyphylla*, *Mallotus philippensis*, etc. In wasteland and pastures *Urtica dioica*, *Argemone mexicana*, *Rubus ellipticus*, *R. lesiocarpus*, *Rosa moschata*, etc. are sparingly distributed.

MATERIAL AND METHODS

The material for the present pollen analytical investigation includes surface samples and 1·8 m deep sedimentary core. The surface samples (moss cushions) were picked up at 50 m interval from the vicinity of Dewar Tal for the evaluation of modern pollen/vegetation relationships in the area. The sedimentary core was procured from the swampy lake basin through Hiller's peat auger. For the present studies, 36 samples were taken out for pollen analysis from this core at 5 cm interval. In addition, three radiocarbon dating samples were also collected from this core at suitable depths.

Four lithozones are discernible on the basis of sediment composition of the core. The top zone comprises fibrous peat

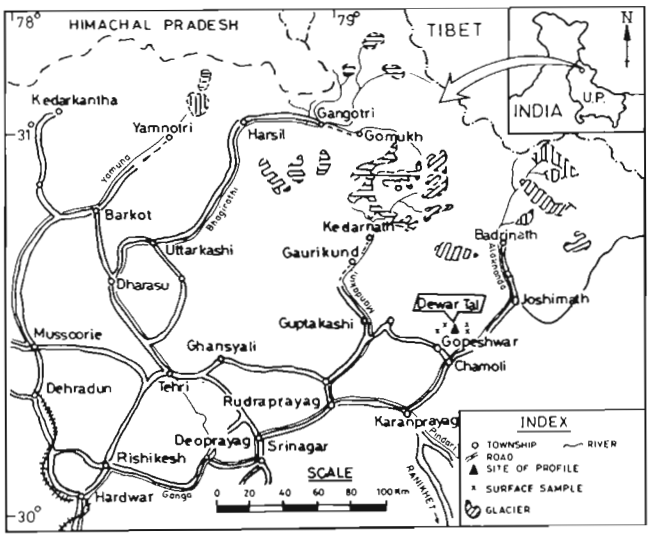

Fig. 1—Sketch Map of Garhwal showing the area of study.

with intermingled rootlets of the existing vegetation on the swamp. This zone rests over peaty-clay zone, which is the thickest lithozone of the recovered Dewar Tal sediment sequence. Below the peaty-clay zone lies well-delineated blackish clay zone followed by the bottom brownish clay zone. The depthwise lithostratigraphical details are given below:

Depth	*Lithology*
0-50 cm	Fibrous peat with rootlets
50-120 cm	Peaty-clay
120-150 cm	Blackish clay
150-180 cm	Brownish clay

The determined three radiocarbon dates of the core at different depths are as follows :

Depth	*Laboratory No.*	*Radiocarbon dates*
80-90 cm	BS-1189	890±120 years BP
125-140 cm	BS-1182	2360±110 years BP
165-180 cm	BS-1181	2430±100 years BP

POLLEN ANALYSIS

Standard technique of acetolysis (Erdtman, 1943) was employed to extract pollen and spores, both from surface and core sediment samples. A minimum of 200 pollen were counted in each sample for the percentage calibration of the recovered taxa. In the reconstructed pollen diagram and pollen spectra the plant taxa have been grouped as trees, shrubs, herbs and ferns.

Modern pollen/vegetation relationship

The analysis of four surface samples collected from the vicinity of Dewar Tal was required for the precise appraisal of the regional pollen spectra to interpret the reconstructed past vegetation (Fig. 2). The study has shown that *Pinus roxburghii* (22-57%) followed by *Quercus* (5-18%) and *Betula* (2-10%) are recorded in good frequencies and their representation corresponds to some extent with their distribution in the regional forests. The other two arboreals- *Alnus* and *Corylus* (1·5-4% each) are also met with but in moderate values, whereas the representation of *Myrica* and *Rhododendron* (2% each) is in extremely low values or sporadic. The poor recovery of all the above taxa can be attributed either to their low pollen production or due to their entomogamous nature, besides partial or poor preservation of pollen in the sediments. The encountered pollen of *Tsuga* (1·5%) and *Cedrus* (1·2-5%), both representing temperate conifers, demonstrates their wind transportation or deposition by water flowing from higher elevations.

The retrieved pollen of Poaceae (11-15%), Cyperaceae (1-20%), Tubuliflorae (2-7%), Malvaceae (1-5%), Cheno/Ams, *Rumex* and *Polygonum plebeium* (2-3·5% each) representing major constituents of the ground cover show a close coherence with their contribution to the extant vegetation in the region. Preponderance of the recovered fern spores (monolete 6-15% and trilete 2-15%) signifies the luxuriant growth of ferns in the area.

Pollen diagram

The pollen diagram has been divided into three pollen zones viz., DT-I, DT-II and DT-III, starting from bottom upward to delineate the reflected vegetational shifts and contemporary attributed climatic changes that occurred in the region during late Holocene (Fig. 3). Pollen Zone DT-II is further divided into three subzones viz., DT-IIa, DT-IIb and DT-IIc. These pollen zones and subzones are prefixed by 'DT' denoting the investigated site- Dewar Tal.

Pollen Zone DT-I (180-145 cm): Pinus roxburghii-Quercus-Poaceae-Cyperaceae-Tubuliflorae- Fern Assemblage

This pollen zone provided with radiocarbon date of 2,430±100 years BP at 165-180 cm depth level portrays almost equal representation of arboreals and non-arboreals. *Pinus* (35-40%) exhibits much higher frequencies compared to *Quercus* (3-8%) which shows moderate values. Among other important associates, *Corylus* and Rosaceae (2-3% each) are met with consistently though in low values, whereas *Betula* (4%), *Bauhinia*, *Cedrus*, *Abies* and *Picea* (2% each) are either sporadic or encountered in extremely low values.

Among the non-arboreals, Poaceae (25-30%) followed by Cyperaceae (5-10%), Tubuliflorae (5-7%) and Ranunculaceae (4-10%) are the major represented constituents of the ground vegetation along with sporadically encountered *Artemisia* and Cheno/Ams (3% each).

Pollen Zone DT-II (145-32·5 cm)

This pollen zone has been further divided into three subpollen zones viz., DT-IIa, DT-IIb and DT-IIc based on significant variations witnessed in the representation of some important forest components.

Subzone DT-IIa (145-120 cm): *Pinus roxburghii-Quercus-Betula*-Cyperaceae-Poaceae-Tubuliflorae-Fern Assemblage—This pollen subzone radiocarbon dated 2,360 ± 110 years BP at 125-140 cm depth brings out much appreciated values of important arboreals such as *Pinus roxburghii* (37-48%), *Quercus* (11-16%) and *Betula* (4-5%) compared to Pollen Zone DT-I. Furthermore, *Corylus* (2-3%), *Myrica* (2%), *Symplocos*, *Ephedra* and *Rhododendron* (1% each) make their first appearance in this subzone. *Viburnum* (2-3%), Fabaceae and Oleaceae (1% each) are the represented constituents of shrubby vegetation in the region.

Poaceae (3-6%) exhibits a sharp decline, whereas Cyperaceae (6-11%) and Tubuliflorae (3-7%) together with fern spores (monolete 2·5-14% and trilete 1-3%) maintain more or less the same values as seen before. The two aquatics, *Potamogeton* and *Nymphoides* are recorded scantily.

Subzone DT-IIb (120-100 cm): *Pinus roxburghii-Quercus*-Poaceae-Cyperaceae-*Potamogeton*-Fern Assemblage—This subzone is marked by the decline in arboreals and simultaneous improvement in non-arboreals. *Pinus roxburghii* (29-31%) and *Quercus* (2-7%) decline considerably, whereas *Betula* (1%) is low and sporadic. Oleaceae (1-3%), *Ephedra* and *Myrica* (2% each) are represented consistently.

Poaceae (27-35%), Cyperaceae (7-25%) and Cheno/Ams (2-4%) have much improved frequencies than the preceding subzone. *Artemisia* (3%), Tubuliflorae and Ranunculaceae (2% each) become more sporadic, but *Polygonum plebeium* (3-5%) together with aquatic elements- *Potamogeton* (5-12%) and *Nymphoides* (2%) have enhanced values. Fern spores (monolete 2-15% and trilete 3%) hardly show any change in their values.

Subzone DT-IIc (100-32.5 cm):*Pinus roxburghii-Quercus-Betula*-Rosaceae-Poaceae-Cyperaceae-*Potamogeton* Assemblage—This subzone radiocarbon dated 890±120 years BP at 80-90 cm depth reveals declining trend in *Pinus roxburghii* (32-12%) with a corresponding improvement in *Quercus* (10-12%) though having fluctuating values. *Rhododendron* (2%), *Myrica* (1-4%), *Betula* (1·5-10%), *Corylus* (1-2·5%) along with shrubby elements such as Rosaceae (2-3%) and Fabaceae (2%) exhibit enhanced values compared to Rubiaceae, *Strobilanthes*, *Lonicera* and *Berberis*, which are encountered in low frequencies.

Although, Poaceae (40-20%) attains its maximum frequency but mostly exhibits fluctuatingly reduced values, whereas Cyperaceae (16-34%), Ranunculaceae (1-10%), Tubuliflorae (3-5%) have improved frequencies. Marshy taxa such as *Rumex* (3%), Apiaceae (2-3%) and *Polygala* (2%) appear sporadically in this subzone. Among the aquatic taxa, *Potamogeton* (1-3%) and *Nymphoides* (1-5%) too exhibit enhanced values. Fern spores (monolete 2-15% and trilete 2%) decline considerably.

Pollen Zone DT-III (32.5-0 cm): *Pinus roxburghii-Quercus*-Cyperaceae-Poaceae-Tubuliflorae Assemblage

In this pollen zone, *Pinus roxburghii* (13-18%) depicts an increasing trend compared to the preceding subzone, whereas'*Quercus* (7-3%) shows fluctuatingly reduced values. Other arboreals such as *Betula* (5%), *Juglans*, *Ulmus*, *Cedrus* and *Picea* (2% each) are encountered more sporadically at

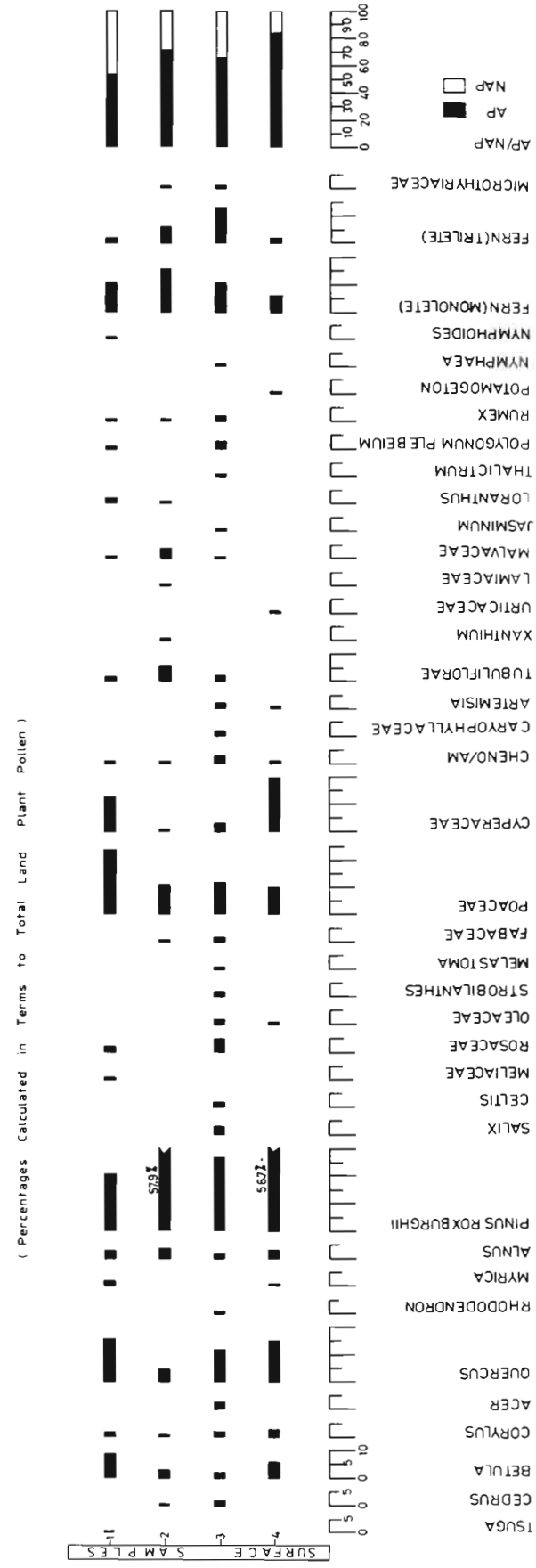

Fig. 2—Pollen spectra from Dewar Tal, Garhwal Himalaya.

the beginning of this pollen zone. Likewise, the shrubby elements viz., *Viburnum* and Rosaceae (2% each), *Berberis*, *Lonicera*, Rutaceae and Oleaceae (1% each) become more sporadic than the Subzone DT-IIc.

Poaceae (13-20%), Cyperaceae (28-40%) and Tubuliflorae (2-4%) are represented with improved values. Cheno/Ams, Liguliflorae (1-3% each) and Ranunculaceae (2%) are low and comparatively more sporadic as observed previously. The two aquatic taxa-*Potamogeton* (3%) and *Nymphoides* (2%) are recovered in moderate frequencies. Fern spores (monolete 2·5% and trilete 2%) dwindle down further in this zone.

VEGETATION AND CLIMATE

The pollen analysed 1·8 m deep sedimentary profile procured from the erstwhile subtropical Dewar Tal lake situated in the Inner Lesser Garhwal Himalaya has yielded interesting proxy data to understand precisely the palaeovegetation succession and corresponding climate changes in the region during the late Holocene. The derived pollen sequence indicates that between 2,500 and 2,300 years BP, the exposed sunny slopes of the hills surrounding the present swampy lake had chirpine (*Pinus roxburghii*) dominated open forest, whereas oak forest flourished in the moist and shady depressions in the vicinity of the lake. *Bauhinia* and members of Rosaceae were sporadically distributed associates of the oak forest. The ground vegetation was poor and comprising chiefly grasses associated with sedges and members of Asteraceae and Ranunculaceae. The sparsely occurring and open forests signify that the region was under cool and dry climate during this period.

Expansion of these forests is witnessed between 2,300 and 2,000 years BP as evidenced by the improved frequencies of the two most prominent arboreals-*Pinus roxburghii* (chirpine) and *Quercus* (oak), and simultaneous invasion of several broad-leaved elements like *Rhododendron*, *Myrica*, *Symplocos* and *Viburnum*, though represented sporadically in low frequencies. The herbaceous ground vegetation- especially grasses and sedges dwindled sharply in these thick forests. The overall vegetational scenario demonstrates that the changed climate was conducive for the growth and spread of the main forest arboreal taxa. In consequence to the amelioration of climate, the temperate elements like *Betula* and *Carpinus* also entered and flourished well on the higher elevations as evidenced by their increased pollen frequencies in the sediments.

Later on, the chirpine and oak forests had a sharp retreat for a short time span between 2,000 and 1,400 years BP as evidenced by the decline in *Pinus* and *Quercus* frequencies

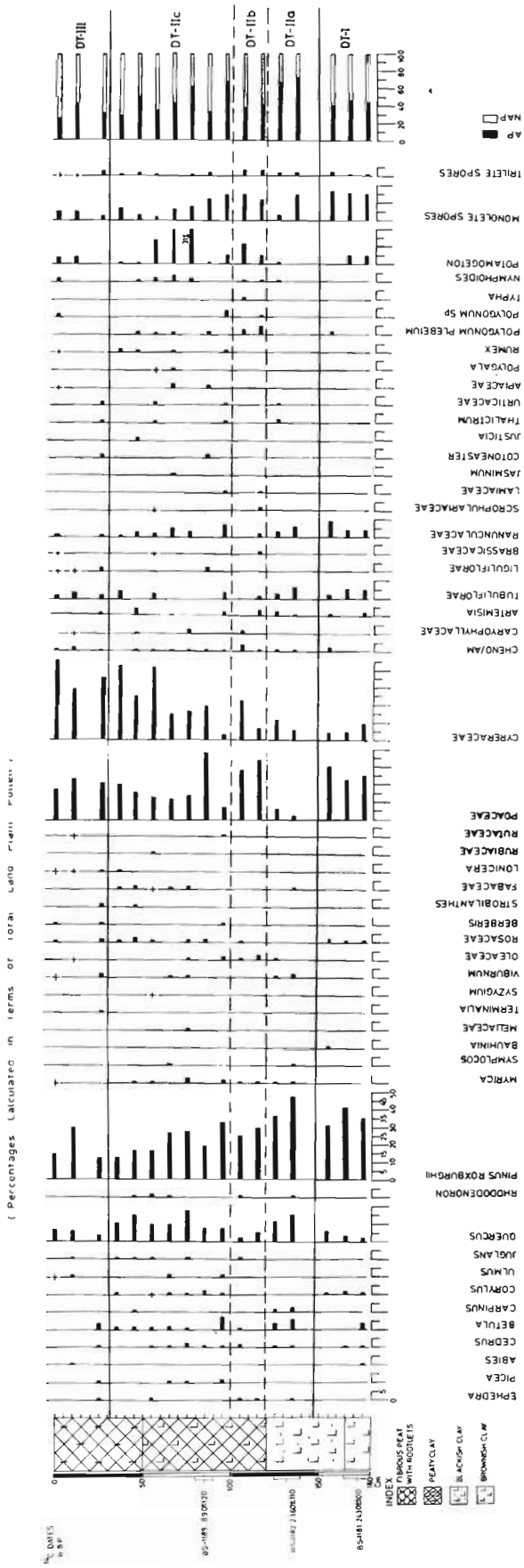

Fig. 3—Pollen diagram from Dewar Tal, Garhwal Himalaya.

and simultaneous improvement in grasses and sedges for a brief span of time. This subtle change registered in the floristic composition demonstrates that cool and dry climate returned once again in the region, but for a shorter interval. Enhancement in grasses and sedges together with better represented *Polygonum plebeium* and the aquatic elements-*Potamogeton* and *Nymphoides* reflect the inception of swampy condition along the lake margin during this phase.

Soon after, between 1,400 and 400 years BP, oak forest attained its maximum development and its associates such as *Rhododendron* and *Myrica* also reappeared on the scene, whereas *Juglans*, members of Fabaceae and Rosaceae were also better represented. This change is associated with simultaneous steady decline in the mixed chirpine forests in the region. Increased precipitation in the region must be plausible factor attributable to the marked improvement in the mixed oak forests. Excessive silting supported by profuse growth of sedges, good representation of *Polygonum plebeium* and some aquatic taxa like *Potamogeton* and *Nymphoides* bear evidence to gradual transformation of the lake into present day swamp. Chronologically, the latter part of this climatic phase coincides closely with the Medieval Warm Period, widely reported from Europe (Lamb, 1977) or "Little Climatic Optimum" as recorded in America between 700 A.D. to 1,200 A.D.

The retrieved pollen data covering the period of last 400 years BP (1,550 A.D.) or so have registered gradual decline in the mixed oak forests as well as contemporary rise in chirpine dominated forests as seen today in the region. Other broad-leaved associated arboreal components such as *Juglans*, *Myrica* and *Terminalia*, together with shrubby *Viburnum*, *Strobilanthes*, Oleaceae, Rosaceae, etc. were scantily distributed in the chirpine forests. This change in palaeovegetational scenario depicts the deterioration in the climate which most probably turned to more cold and dry compared to the earlier condition. The lake also turned into a big swampy flat land during this cold and dry phase by the maximum expansion and proliferation of sedges in and along the lake margin. Advent of anthropogenic activity and gradual enhancement in agricultural practices is evidenced on the basis of encountered culture pollen taxa such as grasses, Cheno/Ams, *Artemisia*, Caryophyllaceae and Urticaceae right from the beginning of the pollen sequence.

CORRELATION WITH THE POLLEN PROFILES ANALYSED FROM OTHER AREAS

On correlation of the pollen sequence emerged through the investigation of sediment core from the subtropical lake, Dewar Tal with those already available from the other sectors of Himalaya, some common climatic features have been recorded since 2,500 years BP, irrespective of their entirely diverse floristic compositions. The subtropical belt around Dewar Tal experienced a cool and dry climate during 2,500 to 2,300 years BP Similarly, the cool temperate and cold and dry climatic conditions prevailed in the temperate belt of Uttarkashi around 2,000 years BP (Chauhan *et al.*, 1997) and alpine belt of Lahul Spiti (H.P.) around 2,300 years BP (Chauhan *et al.*, 2,000) respectively. The temporal difference of 200 to 500 years for the prevalence of almost equivalent climatic regime could be attributed to the altitudinal control of climatic variance in these regions. Subsequently, an amelioration in climate had occurred between 1,400 to 400 years BP in Dewar area and this also exhibits some correspondence with the identified climatic episodes in the subtropical belt of Himachal Pradesh (Sharma & Chauhan, 1988), the temperate belt of Uttarkashi (Sharma & Gupta, 1995) and alpine belt of Lahul Spiti (H.P.), around 1,000 years BP, 1,500 years BP and 1,500 to 900 years BP respectively. At global level this phase lies within the time frame of Medieval Warm Period (Lamb, 1977) as recorded in Europe and America between 1,200 to 950 years B.P (740 to 1,050 A.D). The present phase, which is marked by the deterioration of climate commenced around 400 years BP at Dewar Tal area. However, it has been recorded quite earlier i.e., 1,200 years BP in the temperate belt of Uttarkashi and around 900 years BP in the alpine belt of Lahul Spiti (H.P.) in response to varying altitudinal control of the climatic factors in these regions.

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