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QUATERNARY PALAEOBOTANY/PALYNOLOGY IN THE HIMALAYA: AN OVERVIEW

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ABSTRACT

The overview appraises critically the work on Quaternary palaeobotany/palynology carried out in the Himalaya during last over hundred years. The fluctuations in cool and temperate vegetation and climate during the early Quaternary (Lower Karewas), aspects of vegetational development during the last glaciation and during present interglacial period impart a glimpse of the changing patterns of vegetation through the Quaternary period. Further, it urges the construction of more pollen diagrams, intensification of researches on the comparative data base together with increased indigenous ecological insight and the sophistication in methodology to bring out invaluable information of biogeographical, geological and archaeological interests. The history of lake basins and fluctuations in hydrochemistry should be built up through the studies of diatoms in conjunction with pollen and spores.

The studies of the evolution of Quaternary floristics should not overlook the historical perspective, i.e. its evolution from the Miocene/Pliocene flora. The recognition of transitional stage in the evolution of flora is highly imperative to demarcate the Neogene/Quaternary boundary on botanical grounds. A few names for various stages (vegetational/climatic phases) during the Quaternary have been proposed after the type sites in keeping with the Code of Stratigraphical Nomenclature for their use in bio- and chronostratigraphy. Besides, it emphasises the importance of indigenous ecological insight in solving the ecological problems and biogeographical riddles in the diversity of floristics in the Himalaya, and to determine the rate and extent at which the forests in the Himalaya have been adversely affected by the progressive increase in land use and by the progressive and selective exploitation of the forest constituents.

Key-words—Palaeobotany, Palynology, Palaeoecology, Quaternary, Himalaya (India).

साराँश

हिमालय का चतुर्थक युगीन पुरावनस्पतिक/परागाणविक अध्ययन : एक विशेष समालोचना – विष्णु-मित्र

पिछले लगभग सौ वर्षों में हिमालय पर किये गये चतुर्थक युगीन पुरावनस्पतिक/परागाणविक अध्ययन की विस्तृत समीक्षा की गई है। प्रारम्भिक चतुर्थक युग (अधरि करेवा) में ठंडी व शीतोष्ण वनस्पति एवं जलवायु के उतार-चढ़ावों तथा अन्तिम हिमानी व वर्तमान अन्तरहिमानी काल में हुए वनस्पतिक विकास से चतुर्थक युग में वनस्पति के बदलते स्वरूपों की झलक मिलती है। इसके अतिरिक्त और अधिक परागकण-चित्र बनाने, ठोस तुलनीय आँकड़ों के आधार पर अनुसंधान में गति लाने तथा जैवभौगोलिक, भूवैज्ञानिक एवं पुरातात्विक जानकारी प्राप्त करने के लिए नवीनतम् विधियों के प्रयोग हेतु आग्रह किया गया है। इसके साथ-साथ यह प्रस्तावित किया गया है कि परागकणों व बीजाणुओं के सहयोग से डाऐटमों के अध्ययन द्वारा जलरसायन की अस्थिरताओं तथा झील द्रोणीयों के इतिहास का अन्वेषण किया जाना चाहिये।

मध्यनूतन/अतिनूतन वनस्पतिजात के द्वारा चतुर्थक वनस्पतिजात के विकास का अध्ययन करते समय ऐतिहासिक स्वरूप को भी विशेष महत्व देना आवश्यक है। वनस्पतिक आँकड़ों के आधार पर पश्च-तृतीयक/चतुर्थक युग का सीमाँकन करने के लिए वनस्पतिजातीय विकास की अन्तरवर्ती अवस्था पर बल देना अत्यावश्यक है। चतुर्थक युग में विद्यमान विभिन्न चरणों (वनस्पतिक/जलवायवी अवस्थायें) के लिए स्तरिकीय नामपद्धति संहिता के अनुसार कुछ नये नाम भी प्रस्तावित किये गये हैं जिनका जैवस्तरिकी एवं कालस्तरिकी में उपयोग किया जा सकता है। इसके अतिरिक्त हिमालय में पाई जाने वाली वनस्पतिक विविधता की पारिस्थितिक समस्याओं और जैवभौगोलिक रहस्यपूर्ण गुत्थियों को सुलझाने के लिए स्वविकसित पारिस्थितिक अन्तरदृष्टि तथा हिमालय की भूमि के तेजी से बढ़ते उपयोग एवं यहाँ पाये जाने वाले विशेष वन्य तत्वों के विनष्टीकरण की सीमा एवं दर सुनिश्चित करने पर भी विशेष बल दिया गया है।

INTRODUCTION

THE information on Quaternary Palaeobotany of the Himalaya commenced accumulating in the middle decades of the nineteenth century when the occurrence of leaf impressions in the Lower Karewa deposits of Kashmir Valley was brought to light by the early geologists (Godwin-Austen, 1864). To this, Middlemiss (1910) added several taxa identified from leaf impressions. A comprehensive list of plant remains from the Lower Karewas, identified by Prof. R. R. Stewart, together with climatic and geographical aspects of this flora, was published in 1939 by de Terra and Paterson. Puri in a series of papers described and figured a bulk of Lower Karewa leaf impressions, synthesized the data and discussed their phytogeography (Puri, 1945, 1948a, 1948b, 1957). In 1965, all the taxa identified from leaf impressions and discovered from the Lower Karewas in Kashmir Valley were reconsidered ecologically and in relation to stratigraphy (Vishnu-Mittre, 1965a). Robert's (1967) re-examination indicated the occurrence in them of some elements matching with the leaves of eastern Himalayan extant taxa. Awasthi and Guleria (1982a, 1982b) have recently added fresh information on leaf impressions and carbonized woods from the Lower Karewas.

It was in 1935 when the first results of pollen analysis of Upper and Lower Karewa sediments were published by Wodehouse and de Terra. Two years later Deevey (1937) described fossil pollen spectra from second interglacial sediments of Panggong Lake. Puri (1948a) too had pollen-analysed some samples. Diatoms and algae have been reported by Conger (1939) and Iyengar and Subramanyam (1943).

The pollen analytical work resumed in the mid fifties in the Himalaya (Nair, 1960) has been continued comprehensively at the Birbal Sahni Institute and elsewhere ever since (Dodia *et al.*, 1982a, 1982b, 1982c; Gupta, 1971, 1973, 1977; Gupta & Khandelwal, 1982a; Gupta *et al.*, 1982a, 1982b, 1982c; Gupta & Sharma, 1982; Mehrotra, Pal & Srivastava, 1979; Rawat, 1982; Robert, 1967; Sharma, 1972, 1973, 1976; Sharma & Singh, 1974; Sharma, B. D. & Vishnu-Mittre, 1969; Singh, 1963; Singh & Agarwal, 1976; Tewari, Swain & Sharma, 1979; Tewari, Swain & Awasthi, 1979; Vishnu-Mittre, 1963, 1964, 1965a, 1965b, 1966a, 1966b, 1972a, 1972b, 1973a, 1973b, 1974a, 1974b, 1974c, 1974d, 1979, 1980a, 1984; Vishnu-Mittre, Singh & Saxena, 1962; Vishnu-Mittre & Sharma, B. D., 1966; Vishnu-Mittre, Gupta & Robert, 1967; Vishnu-Mittre & Robert, 1971; 1973, Vishnu-Mittre & Gupta, 1971; Vishnu-Mittre & Sharma, C., 1984; Vishnu-Mittre & Bhattacharyya, 1980, 1983).

Studies on fossil algae since 1960 have been carried out by Goswami (1955), Rao and Awasthi (1962), Roy (1970, 1971, 1972, 1975, 1979), Gupta and Khandelwal (1982b), Mohan *et al.* (1982a, 1982b) and Swain (1982) and on fossil fungi by Purekar (1962). Studies on plant remains from the archaeological sites in the Himalaya have been carried out by Buth, Bisht and Gaur (1982), Ghosh and Lal (1961), Savithri (1976), Sharma, A. K. (1979-80) and Vishnu-Mittre (1966b, cf. 1974).

In the Upper Siwaliks in the sub-Himalayan region, where the Pinjor and the overlying conglomerates are believed to date from the Quaternary period the pollen analytic work has been carried out by Saxena and Singh (1980, 1982a, 1982b), Singh and Saxena (1981) and Singh *et al.* (1973), cf. Singh (1982).

The concise historical account outlined above reveals rapid progress, during the last two decades, in our knowledge of the Quaternary palaeobotany/palynology in the Himalaya. The growth of this knowledge has been lopsided; most efforts have been confined to the Jammu and Kashmir State, particularly to the Kashmir Valley. During the last two decades not only the efforts have been intensified in this region but the investigations have also been extended to the adjoining states of Himachal Pradesh, Kumaon and Nepal with the eastern Himalaya receiving scant attention.

A broad and a general glimpse into the evolution of Quaternary flora of the Himalaya has indeed emerged from these studies. The chief objective of this overview is not only to appraise critically the work hitherto accomplished bringing out areas requiring intensified research but also to draw attention toward the adoption of the new and current approaches.

EVOLUTION OF EARLY QUATERNARY VEGETATION AND CLIMATE

Kashmir Valley

The early Quaternary Flora known from its remains from the Kashmir Valley was of a varied nature comprising angiosperms, gymnosperms, pteridophytes and algae, particularly diatoms.

Comprising over 100 species and belonging to 65 genera of 36 natural orders, the macrofossils, mostly foliar impressions, have shown rarity of gymnosperms and ferns against the abundance of angiosperms. From their over-all quantitative estimates and cumulative considerations, the oak conifer mixed woods have been reconstructed (de Terra & Paterson, 1939; Vishnu-Mittre, 1965a, 1966a). The data have allowed reconstruction of the submerged, free floating and the reedswamp communities of the Karewa Lake, besides various storeys including the climbers and riverain vegetation that constituted these forests (Vishnu-Mittre, 1965a, 1966a). It was a predominently temperate flora with a small proportion of tropical/subtropical elements such as *Ficus cunia*, *Mallotus philipensis*, *Pittosporum eriocarpum*, *Wendlandia exserta*, *Odina wodier*, *Woodfordia floribunda* and species of *Berchemia* and *Myrsine*. The modern maximum altitudinal limit of these tropical and subtropical elements approaches 1,700 m above mean sea level. The climate was temperate and not tropical as inferred by Puri (1957).

Considered sitewise, the Ningle Nullah flora on account of the absence of oaks appears distinct from the Liddarmarg, the Laredura and the Dangarpur floras. The abundance of *Quercus incana* and *Q. glauca*, the only oaks, together with the species of *Litsea*, *Cinnamomum*, *Machilus* and *Phoebe* distinguishes Liddarmarg flora where not only the species of *Quercus* (*Q. semecarpifolia*, *Q. ilex*, *Q. dilatata*) are different but members of Lauraceae are absent. The Dangarpur Flora has the same kind of *Quercus* spp. as at Laredura but it has a member of Lauraceae (*Litsea elongata*) too. Is this apparent distinction in these floras real and finally established ? Extensive collections from these sites may provide the answer. Unaware of de Terra and Paterson's statement that these floras were contemporary and belonged to a part (Lithozone 4) of the Lower Karewas, Puri (1957) constructed the evolution of the entire Quaternary vegetation from these floras (cf. Vishnu-Mittre, 1965a).

Pollen analysis of the random leaf impression bearing sediments from these sites by Vishnu-Mittre and Robert (1973) has revealed that these floras are not really distinctive as they apparently seem to be. Pollen grains of oaks occur predominantly in the sediments of Ningle Nullah against their absence in macrofossils. The abundance of leaf impressions of oaks at Laredura is represented by under 20% of *Quercus* pollen and at Liddarmarg by 15-20%. At Botapathri where only leaf impressions of *Quercus incana* and *Q. glauca* have been recovered, the pollen evidence shows spruce-oak-deodar woods with pollen of oaks being 20-30%. The pollen analysis of the leaf impression bearing sites reveals that the conifer mixed oak woods had occurred as the regional vegetation during Lithozone 4 to which these sites belong. The apparent floristic differences in the macrofloras of these sites may be attributed among other causes to former varying consocies within this regional vegetation.

Judging from the present day climatic requirements of the taxa identified, the occurrence of *Betula utilis* with *Alnus nepalensis* at Ningle Nullah; of *Quercus semecarpifolia* and *Litsea elongata* at Dangarpur; of *Q. semecarpifolia*, *Q. ilex* and *Q. dilatata* at Laredura and Dangarpur; of *Q. incana* and *Q. glauca* with *Betula utilis* and of *Acer pentapomicum* and *Acer oblongum* with subtropical element at Liddarmarg may cast doubt on the validity of identifications. Considering the identifications unquestionable, one may be compelled to believe that the climatic requirements of these taxa during the early Quaternary were different and their present day climatic requirements have evolved in course of time.

The identity of macrofossils to specific level provides the unequivocal evidence for the former occurrence of the species in local or adjacent environs. It has distinct advantage in this regard over pollen and spores which with rare exceptions can not be run down to specific level. This shortcoming in pollen/spores is accompanied by their ubiquitous nature so that they allow reconstruction of regional vegetation against the local or adjacent from macrofossils. Both are thus complementary to each other in particular regard to the reconstruction of vegetation and environment. Most herbs are unrepresented and the conifers under-represented in the macrofossils. At the same time there are several common taxa in both which enhance the complementary status of both the micro- and macrofossil evidences.

Further, pollen evidence can allow reconstruction of fluctuations in the past vegetation and the relative percentages of pollen grains can be matched with the relative proportions of their mother plants in the forest communities. Pollen evidence thus has additional advantages over macrofossils. For a fuller reconstruction of past vegetation and climate they ought to be considered together. In the event of either of the evidences available, the local or adjacent significance of macrofossils against the regional of the microfossils should not be overlooked in drawing inferences of past vegetation and environment.

The early pioneering attempts on pollen analysis of stray Quaternary sediments from Jammu and Kashmir State (Wodehouse & de Terra, 1935; Deevey, 1937; Puri, 1948a; Nair, 1960) are significantly important in suggesting that the sediments are polliniferous besides providing a glimpse of the kinds of plants that had existed when these sediments were deposited. However, Nair (1960) alone endeavoured to build up fluctuations in the past vegetation even though measurements of the sections and the intervals between samples analysed were not given in his paper. Also no mention was made of the lithostratigraphy adopted. However, he confirmed palynologically the former occurrence (in the Lower Karewas) of *Alnus*, *Carpinus* and *Quercus* already known from macrofossils, though *Larix* and *Pinus roxburghii* were not recorded in macrofossils. The latter two have not been found in subsequent macrofossil studies (Awasthi & Guleria, 1982a, 1982b).

The pollen analysis of five type sites — Sedau, Laredura, Nichahom, Raithan and Botapathri (Text-figs 1-5) in the fine lithostratigraphy of de Terra and Paterson (1939), enabled Vishnu-Mittre (1973a) to infer fluctuations in temperate vegetation interspersed by cool oscillations. The entire reconstructed sequence was referred to the early Pleistocene the commencement of which was indicated at its base. The first forestless condition designated as the First Cool Oscillation after the decline of the oak-alder phase was equated with First Glaciation. The commencement of Glacial Epoch was suggested to be not coeval with that of Pleistocene. In the absence of any physical evidence of a glaciation, cryoturbation, permafrost, etc. within the Lower Karewas, the first and the subsequent cool oscillations should not be equated with glacial events, for the unequivocal botanical evidence indicating that is still lacking. The forestless conditions may be attributed to intensely dry summers and very cool winters. The only undisputed physical evidence of a glaciation occurs on top of the Lower Karewa deposits. And this on the present evidence is in fact the first glaciation which was referred to second by de Terra and Paterson. The evidence for the first glaciation advanced by de Terra and Paterson has not been confirmed by Wadia (1951), Vishnu-Mittre (1964) and Bhatt (1976).

The immigrating and expanding blue pine (*Pinus wallichiana*) subsequent to the First Cool Oscillation constituted first the open blue pine forests changing into the dense blue pine mixed forests. Subsequent to the Second Cool Oscillation which destroyed pine woods, the pattern of vegetation changed into spruce-oak-deodar woods. Indications of the Third Cool Oscillation are inferred in the opening out of these forests. It has also been suggested that during the temperate phases the average annual precipitation was of the order of 1,000-1,300 mm (Vishnu-Mittre, 1979).

A reconsideration of the nature of climates from the following three major plant communities reconstructed becomes necessary from whatever data are available for the corresponding communities in the western Himalaya (Champion & Seth, 1968). The reconstructed plant communities allow comparisons with the following corresponding forests in the western Himalaya only:

1. Oak mixed woods comprising thermophilous elements.
2. Mixed conifer forests comprising *Picea*, *Abies*, *Pinus* or *Cedrus* with or without some deciduous and evergreen broad leaved elements.
3. The steppe comprising chenopod-grass-sedge-*Artemisia*.

The oak-mixed woods with some *Cedrus* are found at Sedau only where no evidence of macrofossils was found. Precipitation from 1,100-1,200 mm can indeed be inferred (Champion & Seth, 1968, p. 293). Presuming that the oaks identified from macrofossils from Lithozone 4 also occurred in the vicinity at Sedau during Lithozone 1, the oak woods may be presumed to have been *Q. dilatata* forests in which *Q. incana* and *Q. semecarpifolia* occurred freely as they do today. Should this presumption be correct ? If so, then winter was pronouncedly cold with a warm summer and with snow lying for several weeks as in modern *Q. dilatata* forest. Temperatures in such a forest would range from 5.5-15°C with high soil moisture and the precipitation at its lower limit would range between 1,500 and 1,900 mm.

The mixed conifer forests occur today under temperatures cooler than in *Q. dilatata* forest, with normal and good snowfall lying for several weeks with the precipitation being 1,100-1,300 mm. This kind of forest is inferred from pollen evidence of Lithozone 4. However, the macrofossil evidence suggests a mixture of temperate and subtropical species. At Liddarmarg, for instance, *Q. incana* and *Q. glauca* are accompanied by several members of Lauraceae which occur in moist temperate forests (Champion & Seth, 1968) along with temperate species of *Acer*, *Buxus*, *Parrotia*, *Ulmus* and others of subtropical nature. At other sites, *Q. semecarpifolia*, *Q. dilatata* and *Q. ilex* are found associated with many temperate elements and a small proportion of subtropical element. Pollen evidence shows that *Picea* and *Cedrus* were the important conifers along with oaks. Both the evidences together indicate moist temperate conifer-mixed-oak woods, and the estimates of temperature and precipitation given above is based upon modern comparable forests in the Himalaya.

The climatic conditions during the Steppe periods (the Cool Oscillations) can be estimated from the present day distribution of *Artemisia* and chenopods in the Pishin Valley (1,375-1,600 m) in Quetta or above tree limit and below glacier at 2,800 m at Tilel or below snowmelt alpine region in Baluchistan and elsewhere in Himalaya (Stewart, 1982). And this suggests that the climate was cooler and much drier with severe winters. Total precipitation may have been under 1,000 mm.

Against the wet or moist climate inferred from macrofossils of which additional support was derived from geology for the much lower altitude of the Pir Panjal (de Terra & Paterson, 1939), pollen evidence suggests fluctuations between moist temperate and cool but dry climates during the time the Lower Karewa deposits were laid even when the Pir Panjal mountain, the present barrier to monsoon, was of a lesser height. There were fluctuations in the annual precipitation regime from 1,500-1,900 mm, 1,100-1,300 mm to under 1,000 mm.

There is indeed additional botanical evidence to support the earlier one (Sahni, 1936; Puri, 1946) that the Pir Panjal was of a lesser height. The modern comparable forests for the reconstructed plant communities from the Lower Karewas occur between 2,000 and 3,000 m above sea level. In spite of the occurrence of fossil leaves referred to alpine/subalpine taxa (*Betula utilis & Quercus semecarpifolia*), the pollen evidence has not brought out alpine birch-blue pine, birch-fir, fir-oak forests which extend today from above 2,500 m to tree limit. Not only these occur today at much higher altitudes but they are also indicative of cooler periglacial, protocratic or telocratic stages in vegetational development. The steppe stages referred to cool oscillations still lack elements distinctive of full glacial vegetation.

Early Quaternary *Betula utilis* and *Quercus semecarpifolia* from their associated majority of temperate taxa and with some subtropical elements must have had climatic requirements different from what they have today as argued elsewhere in the text or else their identifications be looked into again.

The evolution of the present day alpine communities and the Full Glacial Alpine steppe must be traced to the Glacial epoch which commenced after the Lower Karewa sediments had been deposited. Their absence during the Lower Karewa, as the present evidence suggests, is supported by the absence of physical evidence of glaciation within the Lower Karewas.

Palaeobotanical and palynological data in the background of fine lithostratigraphy of de Terra and Paterson (1939) has brought out interesting patterns of change in the vegetation comprising migration, expansion and decline of some taxa in response to the cool oscillations prior to the First Glaciation (the II by de Terra & Paterson, 1939). *Cedrus* was present in small proportions in Lithozone 1 (Text-fig. 1). The blue pine (*Pinus wallichiana*) immigrated during the First Cool Oscillation in Lithozone 2 (Text-fig. 2), expanded in Lithozone 3 (Text-fig. 3), and declined subsequent to the Second Cool Oscillation (Text-fig. 4) in Lithozone 4 (Text-fig. 5) when the spruce-deodar-oak woods were constituted which changed into *Juglans*-elm open woods possibly in response to the Third Cool Oscillation. Small pollen frequencies of *Abies*, *Picea*, accompanying those of blue pine perhaps suggest that these too immigrated along with blue pine. Among these *Picea* alone eventually became an important constituent of temperate forests. Traces of *Engelhardtia* and *Rhus* in the pollen-diagrams and minor subtropical constituents in the macrofossils during Lithozone 4 are indicative of the trailing subtropical element along with overwhelming temperate elements. The transition between tropical and temperate vegetation has not been brought out which could help to demarcate the beginning of the Quaternary on botanical grounds. That this boundary should be drawn at the base of the Lower Karewas investigated palynologically was suggested by Vishnu-Mittre (1964) and Lithozone 1 was equated with Pinjor deposits in the Siwaliks suggesting the boundary at the transition between Tatrot/Pinjore stages (Vishnu-Mittre, 1964, 1965b, 1972a).

The latest information on past vegetation and climate from the Lower Karewas in Hirpur region (Dodia *et al.*, 1982a) indeed reveals a clumsy and careless work: the samples are stated 30-50 cm apart at p. 23 and the same several meters apart in pp. 24-25; sand samples are also pollen analysed and pollen spectra of all the six samples from Hirpur are not considered in sequential order.

A prominent grass-chenopod-*Artemisia* pollen assemblage from a single lignite sample from Wapzan (Gupta *et al.*, 1982a), believed to be the top of the Lower Karewas, is considered to indicate alpine scrub the like of which occurs in the trans-Himalayan region in Ladakh suggesting cold dry climate even though modern pollen spectra from this region are not known.

The two pollen spectra from sandy samples from Hirpur Locality III show 80-85% pollen of *Pinus roxburghii*. The four lignitic mud samples at this site reveal gradual increase in grasses whereas *Quercus* remains consistently low (10-15%). *Larix* shows high values in one sample (H-68) only and *Carya* in another (H-36) whereas *Juglans* is 3-5% in two samples. Even though all these tree genera do not dominate in samples H-36 and H-68 (wrongly quoted as H-38 by the authors), a warm temperate and humid climate with more precipitation is inferred from them. Increasing high values of grasses and much reduced values of *Larix* and *Careya* in top samples is attributed to deterioration of climate. In complete disregard of the present climatic requirements and associates of *Larix* in the Himalaya, the migration of *Larix* to more congenial environments is believed to have been due to dry cold spell, strong-winds, decreasing precipitation and physiographic change without realizing if the pollen evidence really provides all that information.

Arranged in sequential order and utilizing the climatic inference by Dodia *et al.* (1982a), the six widely separated pollen spectra from Hirpur Locality III indicate that the warm temperate humid climate as indicated by *Carya-Quercus*-Poaceae or *Larix-Quercus-Engelhardtia*-Poaceae (samples 36, 38) was preceded and followed by warm dry outer Himalayan slope climate (subtropical) as inferred from the dominance of *Pinus-roxburghii* (in samples 10 and 70) and thereafter deteriorated as evidenced from Poaceae-cheno-ams-*Quercus-Alnus* and Poaceae-*Quercus-Engelhardtia* respectively (S-164 & S-230). On the whole pre-glacial conditions are inferred in these sediments which on provisional palaeomagnetic evidence are referred to Gauss Normal Epoch (3.41-2.47 million years).

The tropical, subtropical, temperate and alpine climates in the Himalaya are the result of varying altitudes. Did the Kashmir Valley swing like a spring board during 3.41-2.47 million years ago, rising up and down until towards the later part of this time period it had attained altitude as high as in Ladakh. When did it attain the present altitude of 1,800 m is not considered ?

Was *Larix* really forced out of the valley during the Lower Karewa times as is held by Dodia *et al.* (1982a)? Tentatively identified *Larix* pollen has been reported from the Toshmaidan site (Sharma & Singh, 1974) now dated from 15,000 radiocarbon years. Does the pollen evidence support this or does it support any of all the causes for this biogeographical change ? The authors fail to make a distinction between cool and cold oscillation as understood in the Quaternary. Had the climatic conditions that exist today in Ladakh ever occurred in the Kashmir Valley during the Lower Karewa times ? A careful ecological and biogeographical understanding of the data published by Dodia *et al.* (1982a) is highly necessary.

The indication in paper by Dodia *et al.* (1982a) that the three lithotypes, viz., sand, mud and lignite, which occur repeatedly in Hirpur Locality III section and characterized each by ± similar pollen assemblage, is confirmed in brief report by Gupta *et al.* (1982b). Thus, the sand layers are characterized by *Pinus roxburghii*, *Juglans* and *Viburnum*; the mud layers by *Pinus wallichiana*, *Abies*, *Picea*, *Cedrus*, *Betula*, and the lignite layer by *Larix*, *Cedrus*, *Cupressus*, *Juglans*, *Engelhardtia*, etc. Nevertheless, Gupta *et al.* (1982b) infer as many as 15 climatic oscillations (four tropical dry, one tropical wet, one subtropical, four warm and wet temperate, and five cold and dry temperate). These briefly reported pollen assemblages do not suggest the evidence for tropical vegetation complex. The inference of this and the other climatic types requires exercise of much care in the perspective of each lithotype being characteristic of the same pollen assemblage irrespective of its position in the section.

No pollen is observed in sands at the Dubjan site believed to represent the lowermost Lower Karewa (Gupta *et al.*, 1982c). Both the Upper and Lower Lignite bands at this site have ±similar pollen assemblage (high grasses, *Picea*, *Cedrus*, *Cupressus* & *Betula*) whereas the intervening mud layer is characterized by *Pinus roxburghii*, *Alnus*, *Juglans* and *Quercus*. The sequence here is interpreted to indicate warm temperate climate interrupted by a moist subtropical phase.

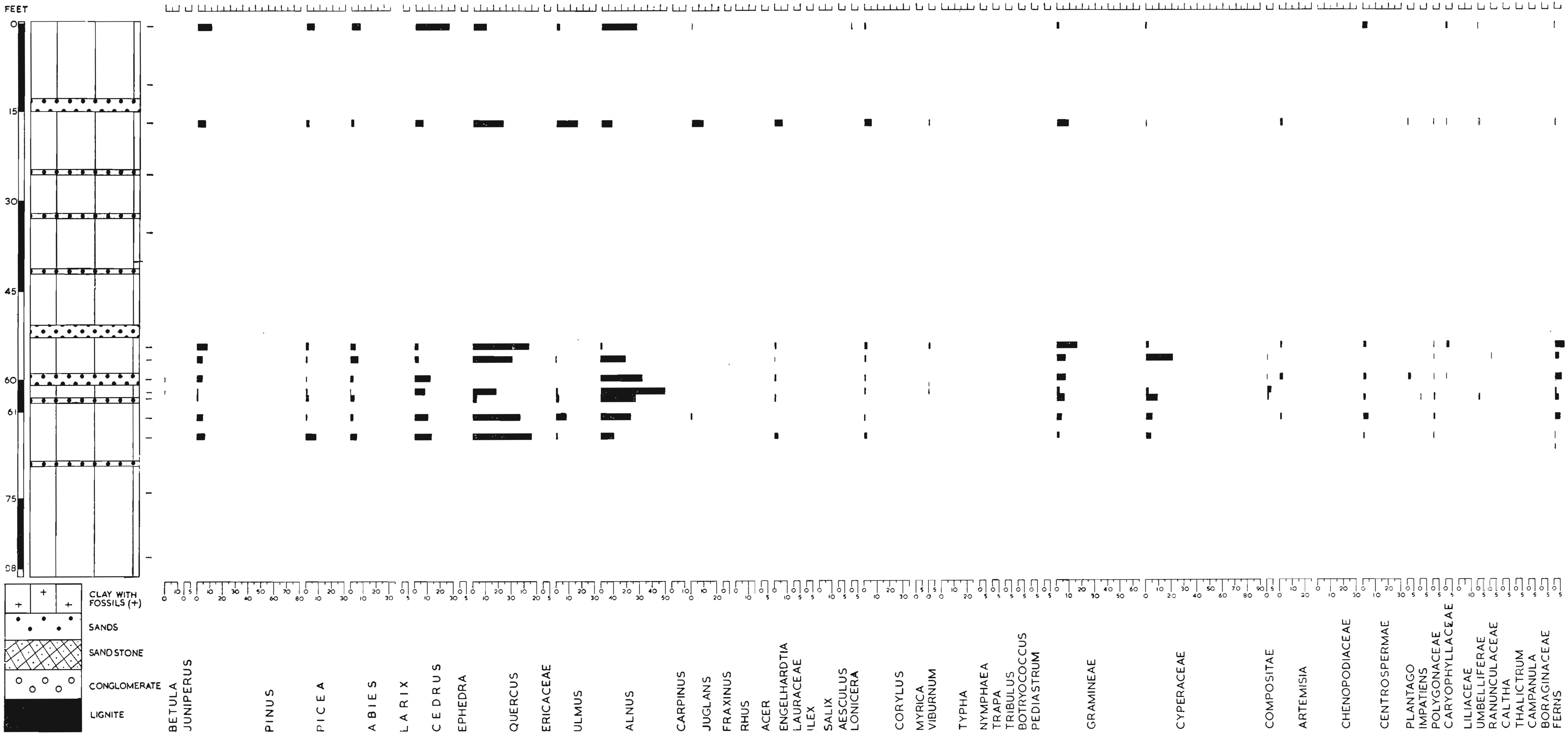
The recent work by Dodia *et al.* (1982a) and Gupta *et al.* (1982b) at the present seems to be a palynological mess and highly confusing. Which way the trend of floristic development is proceeding can not be made out ? The factors which seem to be responsible for this mess in interpretation are overlooked.

A large part of the Hirpur Locality III Section dates from mid- to Upper Pliocene with the top represented by early Pleistocene. More than a dozen climatic oscillations as inferred seem as unusual as the three repeated lithotypes each characterized by the same pollen assemblage irrespective of their position in the section. The latter seems intriguing and its significance not understood properly. It must be pointed out that 2-3 climatic oscillations during the entire Pliocene have been reported from other parts of the world through application of palynology, micropalaeontology and oxygen and carbon isotope studies to both terrestrial and oceanic sediments (cf. Proc. First Int. Conf. on Palaeooceanography held at Zurich, 1983). The Himalayan region by no means could be an exception. If the careful evaluation of the recent palynological data establishes it to be an exception, it would be a very great discovery.

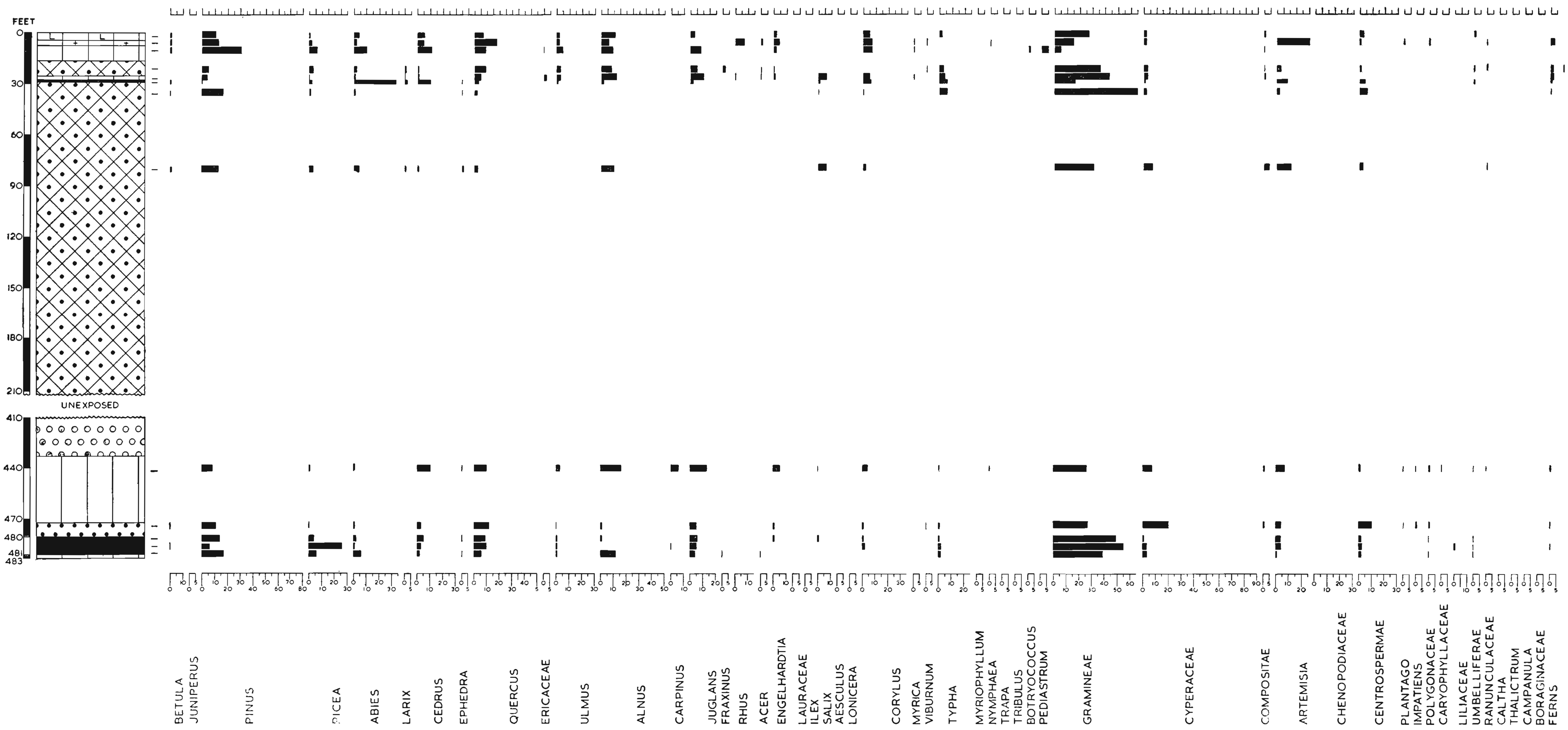
Alongside the recent palynological evidence discussed above there is the macrofossil evidence comprising several taxa reported recently (Awasthi & Guleria, 1982a, 1982b) from the exposures in the Hirpur Formation at Dubjan, Hirpur, Hirpur-Dechhom and Krachipathra in the Upper Rimbiara Valley and from near Raithan in the Shaliganga Valley. The leaf impressions discovered between conglomerates I and II (believed to be within the Gauss Normal Epoch, i.e. 3.41-2.47 m years) are referred to the taxa — *Acer villosum*, *A.* sp., *Aesculus indica*, *Nelumbo* sp., *Populus euphratica*, *Potamogeton* sp., *Ulmus wallichianus*, *Quercus semecarpifolia*, *Rosa macrophylla*, *Salix wallichiana*, *Viburnum cottinifolium*, *Trapa* sp. and *Pteridium aqualinum*.

The fossil woods from sandy layers between conglomerates II and III (believed to be within the Matuyama-Gauss Epoch, i.e. 2.8-1.5 m years: Dodia *et al.*, 1982a, p. 22) are referred to the following taxa — *Abies* sp. cf. *A. pindrow*, *Cupressus* sp. cf. *C. torulosa*, *Fraxinus excelsior*, *Juglans regia*, *Pinus wallichiana*, *Populus* sp. cf. *P. euphratica*.

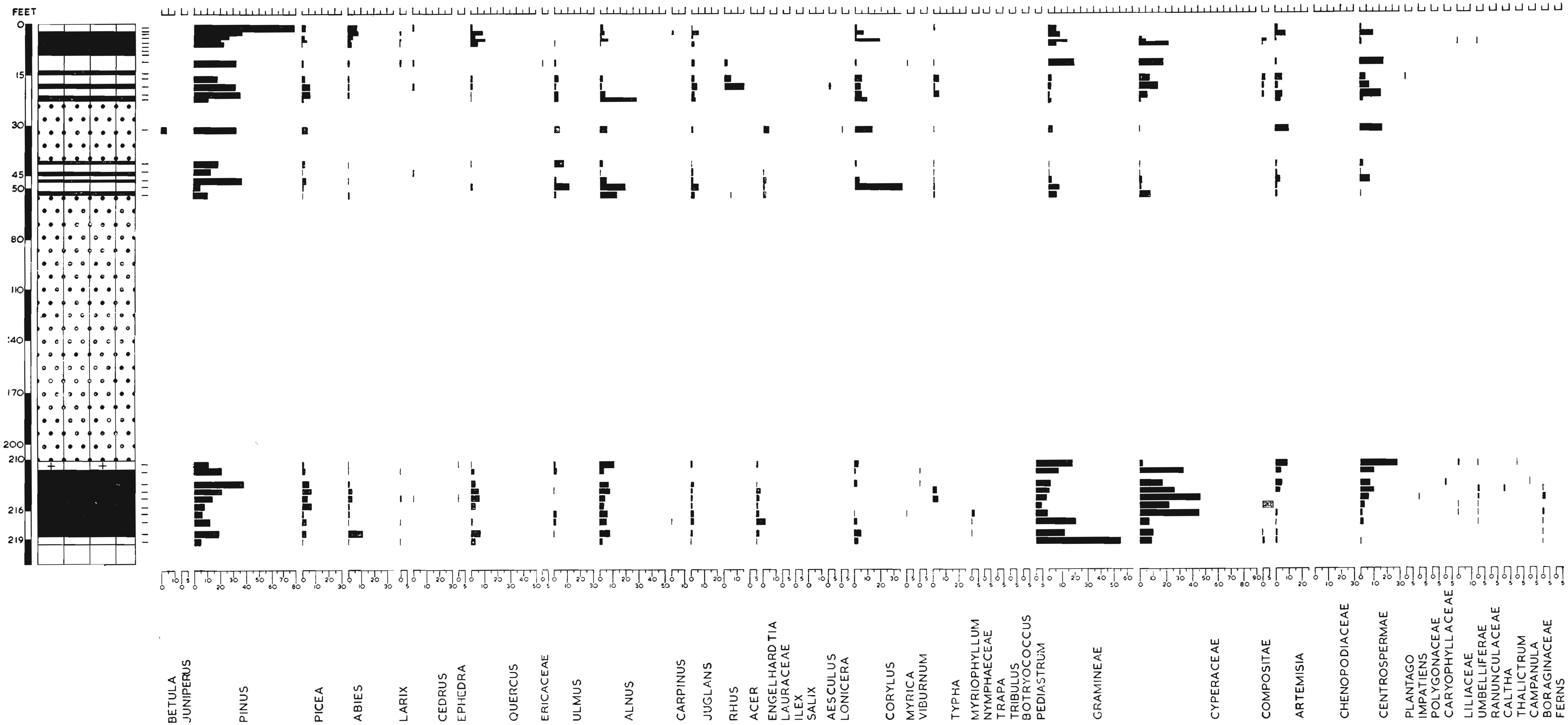
These macrofossils suggest temperate climate from 3.41-1.5 million years supporting the inference of temperate climate from macrofossils from the other Lower Karewa exposures discussed above.



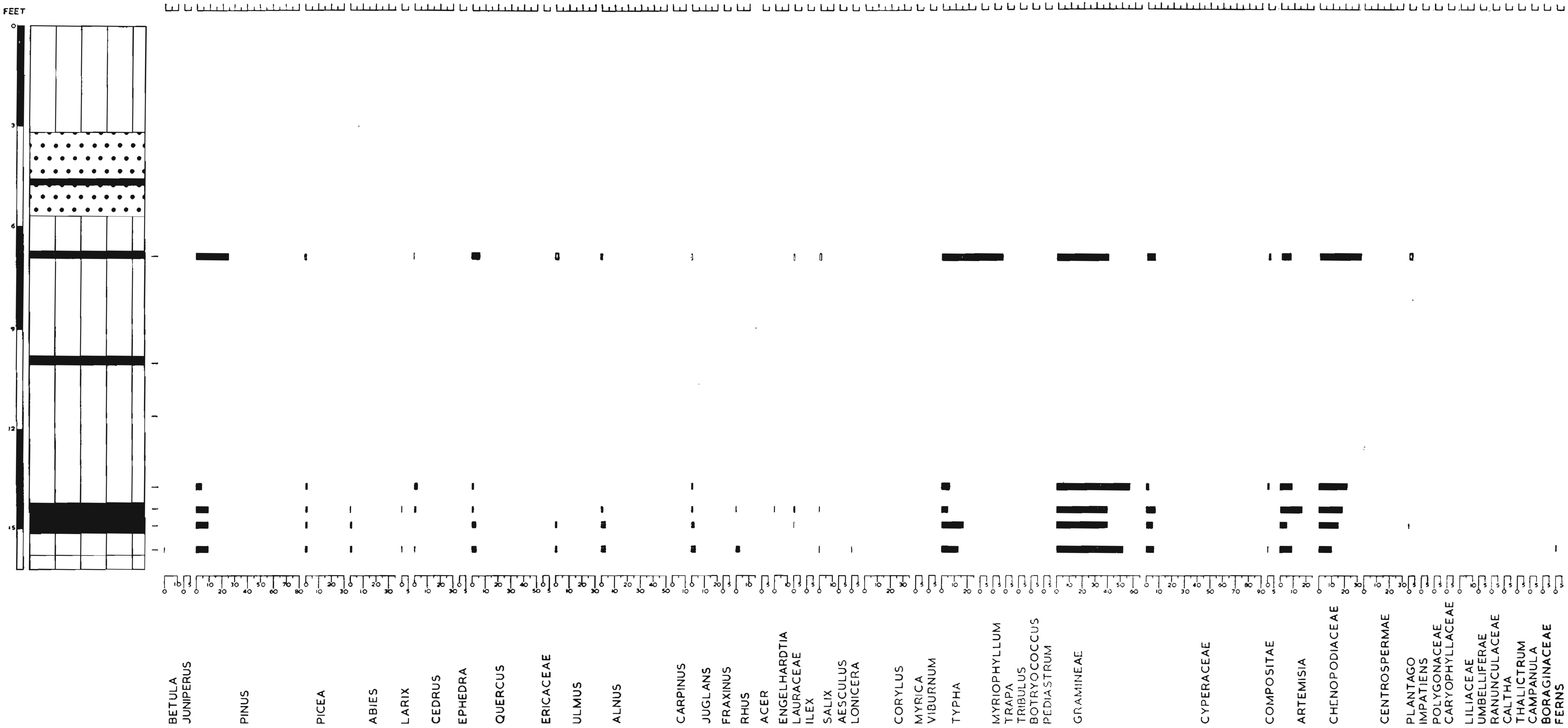
TEXT-FIG. 1 — Pollen diagram from Sedau showing fluctuations in dense oka-alder woods with some deodar and with slight opening of the forest. The extreme top pollen spectra show indications of the formation of deodar-alder-oak-woods.



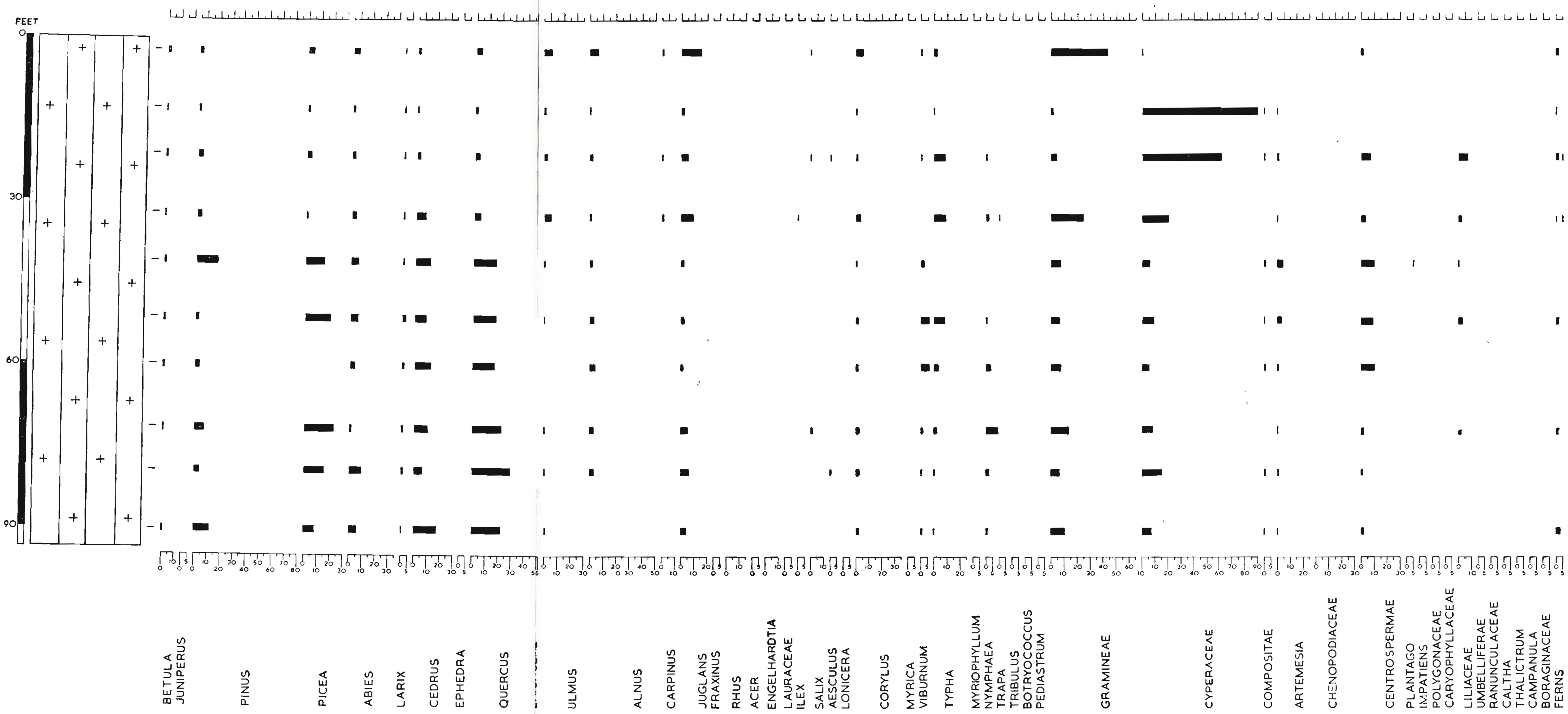
TEXT-FIG. 2 — Pollen diagram from Laredura: The pollen spectra from both the lower and upper lignitic horizons show open conditions with small frequencies of pollen of trees or shrubs. The latter show decreasing trend except *Juglans* and *Alnus* in the lower and rising trend excepting of *Juglans* in the pollen spectra from the upper lignitic horizon. Frequencies of *Pinus*, *Abies*, *Ulmus*, *Salix*, *Corylus*, etc. are much better represented in the lower lignitic horizon. The impact of cool oscillation of climate is apparent in both the horizons of lignite.



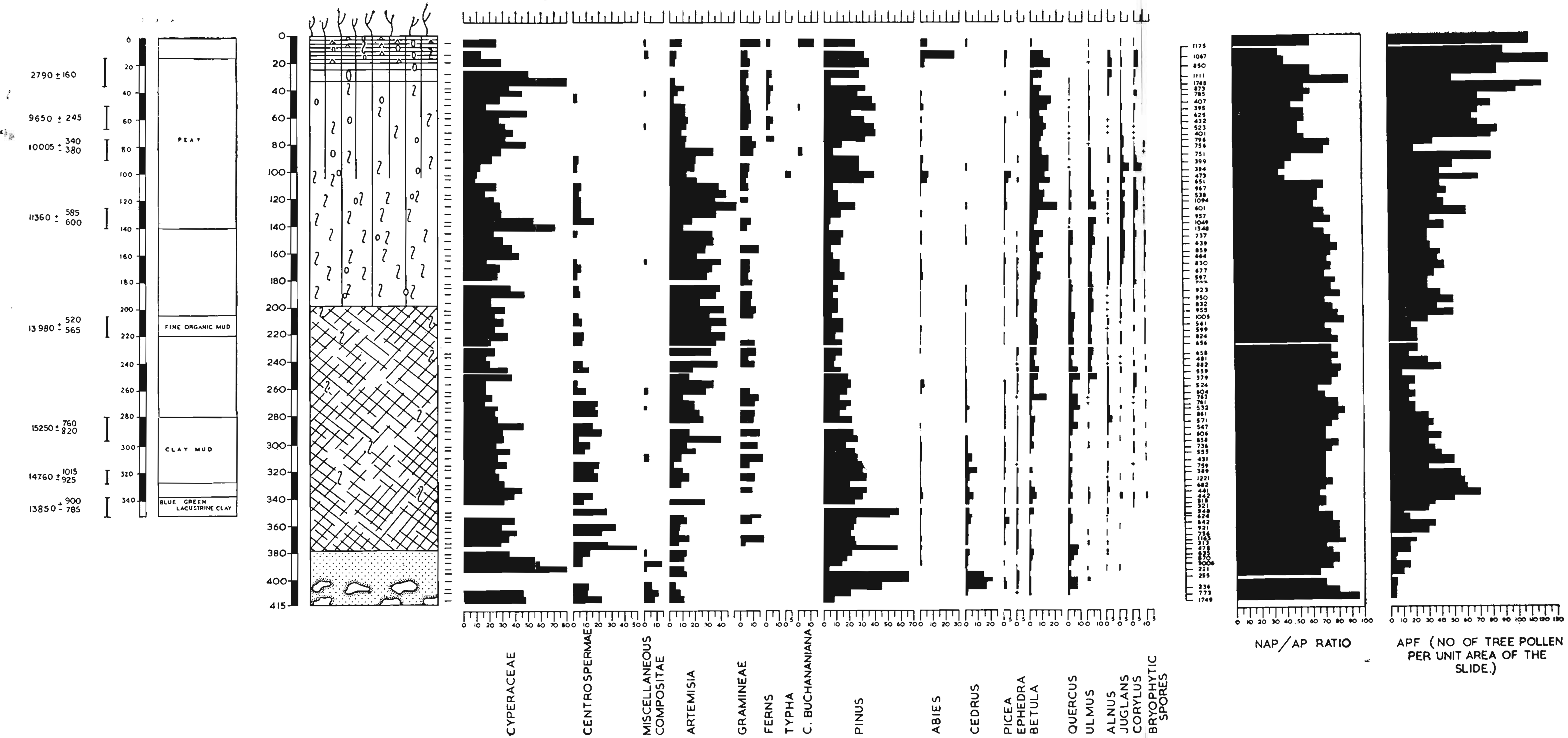
TEXT-FIG. 3 — Pollen diagram from Nichahom: The lower lignitic horizon is characterized largely by steppe which is less represented in the upper lignitic horizon. The upper one is further characterized by much higher values of *Pinus*, *Ulmus.*, *Alnus*, *Rhus* and *Corylus* indicating pine-mixed broad-leaved forest. In the lower horizon, the grass-sedge steppe, the open pine mixed woods and the chenopod-grass-*Artemisia* steppe (Cool steppe-cool temperate-cool steppe) and in the upper, pine-mixed-alder woods increase in steppe vegetation followed by pine mixed oak woods (Warm temperate-cool steppe-warm temperate) are the trends in vegetational and climatic fluctuations.



TEXT-FIG. 4 — Pollen diagram from Raithan: The pollen spectra reveal grass-chenopod-*Artemisia* steppe — The Cool Oscillation.



TEXT-FIG. 5 — Pollen diagram from Botapathri: The deodar-oak woods are succeeded by spruce-oak-deodar woods showing cool temperate climatic conditions. The increase of grasses and sedges and the decline of forest in the top pollen spectra suggest the onset of the Third Cool Oscillation.



TEXT-FIG. 6 — The Toshmaidan pollen diagram reconstructed by the author from the sum of all land plants pollen, from pollen statistics after Singh (1963). On the extreme left is shown the meadow profi with a sequence of radiocarbon dates after Singh and Agrawal (1976).

These macrofossils from below Conglomerate III and provisionally dated through palaeomagnetism provide important palaeobotanical evidence which must be considered along with pollen evidence to reconstruct and interpret alterations in past vegetation and climate. It is interesting to observe that no macrofossil evidence has been found of former occurrence of *Pinus roxburghii* from sand samples, and none of *Larix*. A careful consideration of both the macro- and microfossil evidences may help to clear the mess created by the recent work discussed above.

The mass of botanical information from the Lower Karewas, now dated from the Pliocene to Early Pleistocene, reveals hardly any difference in the Pliocene and Early Pleistocene floristics. Even pollen analysis has not brought out the transition of floristics from the Pliocene into the Early Pleistocene. The species identified with modern taxa tend to suggest that the modern species had emerged during the Pliocene and there was practically no evolution as a result of successive climatic and edaphic alterations which characterized Pliocene and early Quaternary. This would lead us to believe that the modern species have survived, without any change, the ferocity of cooler oscillations intervening the warmer oscillations of climate during this period when the pedogenic processes were equally active. Further, this would indicate that the endemization of several immigrant plant species must have occurred prior to Pliocene. The information on Miocene floristics from the Himalaya does not bear it out (Vishnu-Mittre, 1984). The discovery of ecologically incompatible species in the Lower Karewa floristics shows vis-a-vis their climatic requirements today that the climatic requirements of these species had indeed altered but strangely these were not accompanied by morphographic changes. The identifications need revision to confirm the situation as brought out from this potential time period in the history of Indian floristics, which should in fact provide substantial information on the immigration, expansion and endemisation or extinction of several phytogeographic units which had entered the Himalaya from the surrounding and distant regions and comprise today an enormous bulk of the Himalayan floristics.

Seen in the perspective of the Miocene tropical forests, the denizens of the western Himalaya, the temperate vegetation in the Pliocene shows a sudden change. And there are no known geologic, geomorphologic or climatic events at this transition that can account for this change. It is this serious anomaly which needs a concerted effort for its solution.

It is encouraging that information has brought out several fluctuations in climate during the Pliocene and Early Pleistocene. This overview finds that some of these are not supported by the floristic evidence.

The Upper Siwaliks

Recent palaeomagnetic dating by Opydke *et al.* (1979) suggests that the Upper Siwaliks in the Outer Himalaya date from before 5.44 million years (close of Epoch 5). The deposits referred to the lowermost stage, the Tatrot, were laid during the Gilbert and Gauss epochs. About 2.40-2.50 million years ago, towards the close of the Gauss Epoch, the sediments referred to the Pinjor Stage were deposited and these had continued until beyond 0.72 m years ago. The Olduvai event (1.8-1.6 million years) has been found in the lower half of the Pinjor Stage. However in the Chandigarh region, Yokoyama (1981) has discovered Olduvai event on top of the Tatrot Stage. Palaeomagnetic and Fission Track dating of the Lower Karewas by Burbank and Johnson (1982) reveal that the Upper Siwaliks and the Lower Karewas were contemporary. The Neogene/Quaternary boundary in both remains undecided. In the Siwaliks, however, it is largely believed to be at the transition between the Tatrot and the Pinjor stages or at the base of Pinjor.

Very meagre palaeobotanical information is available from the Upper Siwaliks as compared with that from the Lower Karewas: *Boraginocarpus lakhanpalii*, *Litsea bhatiai* and *Neolitsea pallens* from the Tatrot Stage (Mathur, 1974) and of palms (*Palmoxylon wadiai* & *P. jamuense*) and grasses from the boulder conglomerate (Sahni, 1964; Mathur, 1978).

Pollen grains believed to be comparable with those of *Pinus*, *Podocarpus*, *Alnus*, grasses, *Alsophila* and Cyathaeaceae have been discovered from the transition between the Middle and Upper Siwaliks (Nandi, 1975), whereas of *Pinus*, *Larix*-type (abundant), Araucariaceae, *Magnolia*, grasses and comparatively less of Cyathaeaceae, Schizaeaceae and Parkeriaceae from middle part of the Pinjor Stage near Chandigarh and more or less similar assemblage from the middle part of Pinjor Stage in the Gagret-Bharwain road section in district Una in Himachal Pradesh have been reported. However, the latter differs from Chandigarh pollen assemblage in the absence of pteridophytes and *Magnolia*, *Larix* type is not predominant and angiosperm pollen is 7% in contrast to 23% in Chandigarh Section (Singh & Saxena, 1980, 1981; Saxena & Singh, 1982). From another section extending from Chaksadu in Hoshiarpur to Una in Himachal Pradesh, the lower composite Pollen Assemblage I (made up from the pollen content of 1-25 samples owing to poverty of pollen) shows abundance of *Larix*-like pollen (43%) over bisaccates (9%) in contrast to abundance of bisaccates (77%) and poor *Larix* type (11%) in the upper composite Pollen Assemblage II with pollen of Schizaeaceae, Polypodiaceae, etc. (Saxena & Singh, 1982).

It must be mentioned that the pollen analytical work in the Upper Siwaliks has been carried out from palynostratigraphic viewpoint and the fossil pollen referred to non-commital taxa. The identification of fossil pollen with those of extant himalayan plant species and the climatic inference therefrom have been done very loosely. Besides the evidence of reworking, the remains of fungi (9-14% of total pollen/spore count) have also been found. Except in a few samples, most samples have been found unproductive and the others have extremely poor pollen content.

The sediments in the Upper Siwaliks comprising sandstones, mud-stones and conglomerates are largely fluvial in nature and these were deposited in well-developed meandre regimes which migrated laterally more than once, striking a balance between basin subsidence and fluvial aggradation. The conglomerate deposits were formed owing to decreased sinuosity in stream development and to increase in gradient possibly related to the events of uplift suggesting individual responses to ancient distributary systems in response to local changes in hydrological regimes. The estimated sedimentation rate ranged from 0.33 m/10^3 years to 0.5 m/10^3 years in Pakistan side and this may be the order in the Indian Siwaliks also (Opydke *et al.*, 1979). In the light of these any reconstruction of floristics and climates from the Upper Siwaliks pollen assemblages may be highly misleading.

The overall information available at the present may be taken to suggest that the Pinjor plant remains show a gradual change from the Lower Middle Siwalik floristics in reduction of Cyathaeaceae, Schizaeaceae, Parkeriaceae, *Podocarpus*, and relative increase in *Larix* type pollen and *Pinus* and there is an indication of *Magnolia* also. The section extending from Chaksadu to Una appears to indicate substantial increase of bisaccates towards the top of the section which in lower part of the section were poor with the *Larix* type predominant. There is nothing of this kind of floristic change observed in the contemporary Lower Karewas.

Whether the above floristic change observed in the Pinjor Stage is real or a function of poverty of pollen, inadequate identification, a variable rate of sedimentation and differential destruction of pollen due to oxidation, or effect of fungi needs to be determined. Further, from the biogeographical viewpoint, it ought to be determined if the fossil pollen belong to the extant species or they represent their precursors. Proper identifications will reveal to what extent the east himalayan tropical floristics had continued into the western Himalaya and to what extent the floristics from the surrounding regions had invaded the western Himalaya, expanded and endemized later replacing the tropical floristics prevalent here prior to its advent. The Pinjor Stage in particular is the potential time period which through intensive palaeobotanical/palynological research can yield very valuable information to the above mentioned important aspects of the history of plant geography of the western Himalaya.

Fossil Diatoms

The earliest report on diatoms in Karewas is by Lundquist (1936). Three years later, Conger (1939) published the qualitative and quantitative dominance of Pennales over Centrales in three samples of the Lower Karewas from Handawar and Shaliganga Valley and inferred a rather sizeable, moderately shallow somewhat alkaline or hard water lake at the peak of its productivity.

However, he did not find diatoms in the Upper Karewa sediments. Conger's work enhanced our knowledge of the diatom flora in the Lower Karewas by a dozen taxa not reported by Lundquist (1936).

Later, Iyengar and Subramanyam (1943) from the Ningle Valley and Rao and Awasthi (1962) from Laredura added more taxa to the diatom flora of the Lower Karewas, particularly some endemic taxa. They also reported some taxa in these fresh water deposits which elsewhere occurred in marine and brackish waters. Strangely enough, Rao and Awasthi mentioned marine sediments at Laredura (1962, table 1, p. 89).

Nearly two decades later, Roy (1970, 1971, 1972, 1975, 1979) added 14 genera hitherto unknown from the Lower Karewas. Like Conger (1939) he did not recover diatoms in the Upper Karewas. He also established (Roy, 1972) the Diatom Biozones I and II in the Upper Ningle Valley-Botapathri region, at Baramula and Raithan and Biozone I at Liddarmarg and the other sites and Biozone II at Handawar, Nichahom, Laredura, etc. He also created subzones named after a single taxon.

Roy neither reconstructed palaeoenvironment nor brought out alterations or fluctuations in diatom populations at the sites examined. A large majority among the 30 species identified (Roy, 1972), indeed is of fresh, slightly brackish and eurhaline habitat, but *Synedra crystallina*, *Coscinodiscus marginatus* and *C. morensis* are known from ancient to recent marine sediments. Their occurrence in the majority of fresh to slightly brackish water diatoms may either be due to insecure identifications, their habitat plasticity or due to transport of pre-Karewa marine sediments into the fresh water deposits of the Lower Karewas.

The more or less exclusive occurrence of Centrales (90-98%) in Biozone I and that of Pennales in Biozone II may not be that real as it appears. Evidence for differential destruction or dissolution and diagenesis of silicious tests of Pennales in Biozone I and of Centrales in Biozone II has not been looked into. It is hoped that the future diatom researchers would undertake such studies.

The abundance of Centrales in the Diatom Biozone I and the first appearance of *Navicula* in Biozone II led Roy to assign Mio-Pliocene age to the Lower Karewas. Indeed from historical and phylogenetic viewpoints, the Centrales are the oldest group of diatoms as far best they are genuinely known from the marine sediments from Cretaceous (Albian) onwards, it is during the Miocene (marine) as known from elsewhere that the Pennales, erstwhile quantitatively poor, begin to overtake the Centrales. Among several other pennalean taxa, *Navicula* also appeared in the Upper Miocene (marine) while several centric forms disappeared and others declined.

Should the first appearance of *Navicula* in marine sediments be synchronous with its appearance in fresh water sediments too ? Or should a single taxon in place of floral composition be considered adequate for age determination ? How far the diatom telecorrelations in disjunct and unconnected basins as Mexico and South Asia and even between Alps and the Himalaya are justifiable ? The answers to several such questions would need due consideration of the time involved in evolution and migration of taxa in the background of the plaleogeographical evolution of the basins.

Predominance of Pennales without *Navicula* was reported by Conger, 1939 (cf. de Terra & Paterson, 1939, p. 261) in the Tatrot Stage now dated to Pliocene in the Naushera Salt Range and recently their predominance has been reported in the Pliocene deposits at Hirpur Locality III in the Lower Karewas (Gupta & Khandelwal 1982a). This evidence provides basis for age correlation even between Siwaliks and the Kashmir Valley, the two basins in close proximity.

Roy's work (1972, 1975, 1979) further, and for that matter of his predecessors and the recently reported work (Gupta & Khandelwal, 1982a; Mohan *et al.*, 1982a, 1982b), falls short of the statistical evaluation of diatoms to elucidate the evolutionary and biographic trends such as the extent of the long-living continuous species, the extent of those dying out, the emergence of progressive taxa, their expansion and continuity to the present.

There is practically no work conducted towards the understanding of ecology and development of the Karewa Lake through recognition of planktonic, epiphytic and benthic taxa among the recovered diatoms, through the relative alterations between them and through the overall quantitative evaluation of diatoms per gram of the sediment vis-a-vis the chemistry of sediments to determine alterations in water levels in Karewa Lake and its changing trophic status.

Immature conclusions on past climates have been arrived at (Mohan *et al.*, 1982b) without fresh data-base on the distribution of extant diatoms in various climatic regimes in the Himalaya or without recourse to concerning information published during the last hundred years (Vishnu-Mittre, 1983).

Changes in water level of a lake or fluctuations in its trophic status are responses to climatic and tectonic-geomorphic effects. Total increase in evaporation owing to increase in evaporation rate together with decrease in output by decrease in rainfall is a climatic effect. On the other hand total increase in evaporation resulting from increase in lake surface and further decrease in input by decrease in drainage area (stream capture) is a tectonic-geomorphic effect. Similarly, increase in diatoms of subaerial habitat during a stage when herbs such as *Artemisia*, cheno-ams, caryophylls, etc. predominated indicating severe nature of climate on the mainland is due to erosional phenomena. The diatom distribution is primarily dependent upon edaphic factor rather than climatic factor. The edaphic factor in this concern means the extent of organic matter present, fluctuations between carbon and phosphorous, the clastogenic materials and also the rate of sedimentation, etc.

BIOSTRATIGRAPHY

Vegetational history should always be based upon good lithostratigraphy. De Terra and Paterson's (1939) lithostratigraphical scheme for the Lower Karewa adopted for pollen analysis stood the test of time for some decades. Whereas their evidence for the First Glaciation in the underlying massive conglomerate was disputed as early as 1951 (Wadia, 1951) and subsequently (Vishnu-Mittre, 1965b), their utilization in their scheme of the occurrence of two bands of lignite within the Lower Karewas after Middlemiss (1924) was confirmed in 1958 through detailed mapping and measuring of sections (Mehta & Srivastava, 1958). The mapping and measuring sections led Roy (1972) to recognize four lithozones equivalent to I-IV of de Terra and Paterson, who also built up the diatom stratigraphy of the Lower Karewas.

Without consulting and commenting upon the work of Mehta and Srivastava (1958) on the occurrence of two bands of lignite in the Lower Karewa deposits, Bhatt (1979 cf. Bhatt, 1981, 1982) considered that de Terra and Paterson's fine stratigraphy of the Lower Karewas was based upon presumed correlatability of different lignitic occurrences. Further, he considered that the Lower Karewa outcrops are uncorrelatable owing to unequal folding, erosion and the frequent changes in lithostratigraphy (extreme lateral change in lithofacies). Bhatt (1979) therefore chose conglomerate molasse as a very convenient and handy marker horizon for a field geologist to build stratigraphy, for it occurs in several sections of the Lower Karewas even though it varies in thickness from 6 to 200 m in different outcrops. The three-fold stratigraphy of the Lower Karewas proposed by Bhatt (1979, cf. 1981, 1982) comprises a pre-Conglomerate Zone (Zone 1), a Conglomerate Zone (Zone 2) and a post Conglomerate Zone (Zone 3) as observed in the Type section at Hirpur.

Agrawal *et al.* (1981) reported thin horizons of conglomerate within the post-Conglomerate Zone (Zone 3) at Bhatt's type site, the lower was dated to Gauss normal Epoch (2.47-3.41 m years) and the Upper to Matuyama Reversal Epoch (1.70-1.91 million years). These overly the 200 million thick bottom conglomerate molasse dated to Gilbert Reversal Epoch (3.41-5.44 million years). Attributing these minor conglomerates to minor tectonicity, Bhatt (1982) does not consider these significant for correlation purposes. Their dating to different palaeomagnetic epochs reveals that their significance is perhaps being overlooked and these are certainly not time equivalent with Bhatt's convenient and handy marker, the cemented conglomerate, underlying them. It needs to be proven by isotopic dates that the cemented conglomerate exposed in several sections is time equivalent as believed by Bhatt (1982).

The conglomerate deposits within the Upper Siwaliks in Pakistan have been found to be of varying dates: 5.44 and 4.42 million years respectively at Bhaun at Totrot; 1.9-2.1 million years in Rohtas anticline in Jhelum District; later than 1.9-2.1 million at Mangla-

Samoval anticline (Jhel Khas Section, SW of Kashmir) and to 7,00,000 years at Camphellpur (Opdyke *et al.*, 1979). Yokoyama (1981) dates the upper part of Tatrot, east of Chandigarh to about 1.9-2.1 million years. A more or less similar situation observed in the Lower Karewas, howsoever preliminarily determined at the present trends to reveal contemporaneity of the Lower Karewas with the Upper Siwaliks.

The continuing pollen analytic work has yet to establish the validity of Bhatt's three-fold stratigraphy of Lower Karewas. Utilizing the earlier palynological data (Vishnu-Mittre, 1973a) in this context, the deposits below conglomerate at Laredura (Text-fig. 2) and Raithan (Text-fig. 4) do not reveal similar vegetational pattern. Likewise the exposures at Ningle Nala, Nichahom (Text-fig. 3) Laredura (Text-fig. 2) and Sedau (Text-fig. 1) above conglomerate are also dissimilar palynologically.

Testing the validity of de Terra and Paterson's fine stratigraphy from palynology reveals that the Basal Clay Zone at Sedau (Lithozone 1, Text-fig. 1) and the Upper Clay Zone at Botapathri (Lithozone 4, Text-fig. 5) are distinctly different. So are the Lower and the Upper Lignite Zones (Lithozone 2 & 3, Text-figs 2, 3) at Laredura and Nichahom. The bottom horizon of lignite at Nichahom (Text-fig. 3) portrays continuation of vegetational development with immigrating blue pine into steppe as observed in the Lower Lignite Zone at Laredura (Text-fig. 2). The Raithan Section (Text-fig. 4) correlated with the middle of Laredura Section by de Terra and Paterson (1939) brings out the continuation of the decline of pine forests. The pollen analyses of exposures at Laredura, Raithan and Nichahom above the cemented conglomerate therefore portray the immigration, expansion and decline of blue pine commencing with the First Cool Oscillation and ending with the Second, and this important aspect of vegetational development seems to support the lithological correlation attempted by de Terra and Paterson.

The random pollen analyses of leaf-bearing sediments at Laredura and Liddarmarg justify de Terra's referring these exposures to Lithozone 4 but Dangarpur depicting Deodar mixed conifer woods differs from the other sites in Lithozone 4 (Vishnu-Mittre & Robert, 1973). Systematic pollen analysis of sediments at Botapathri (Lithozone 4) brings out spruce-deodar oak woods leading into the *Juglans-Ulmus* open woods. Detailed and systematic analyses of these sites randomly pollen-analysed and of others may throw adequate light on their correlation with one another.

Recently Pal *et al.* (1980) have reported the evidence of II Glaciation in the cemented conglomerate underlying the Lower Karewas. Earlier de Terra and Paterson (1939) had reported hesitatingly I Glacial evidence in it. Should Pal *et al.* (1980) be correct, then II Glaciation as believed by Pal *et al.* would be as old as 3.41-5.44 million years to which cemented conglomerate in the Lower Karewa is dated now.

In keeping with the Code of Stratigraphical Nomenclature of India, the Lower and Upper Karewas have recently been named after the type sites (Pakharpura & Shopian formations by Farooqi & Desai, 1974; Hirpur & Nagum formations by Bhatt, 1976). Following this, Vishnu-Mittre (1980a) has recently suggested that the distinct vegetational stages in the Lower Karewas should be named after the type sites such as Sedauian for the oak-alder wood stage at Sadau; Nichahomian for the pine mixed woods at Nichahom; Botapathrian for the spruce-deodar-oak wood stage at Botapathri. It is also suggested that the cool oscillation in the Upper Lignitic Horizon at Laredura which is the extension of the one observed at Raithan should be named de Terran; the cool oscillation in the Lower Lignite of Laredura and within the base of Nichahom be named Wadian and the one towards the top of Botapathri as Patersonian to commemorate the names of H. de Terra, D. N. Wadia and T. T. Paterson. The five pollen diagrams accompanying this paper are so constructed that they can be easily superimposed in any of the floating lithostratigraphies to which the sites investigated may be accorded stratigraphical position different from that in de Terra and Paterson's scheme of lithostratigraphy for the Lower Karewas.

LATE QUATERNARY VEGETATION AND CLIMATE AND LAND USE

Vegetation and Climate

The results of pollen analysis of bore-cores dating from 40,000-10,000 radiocarbon years from above tree limit in Ladakh at 34° Lat. and above 4572 m a.s.l. and reported briefly by Vishnu-Mittre and Bhattacharyya (1980, 1983) reveal alterations between the cheno-pod-grass steppe and expansion of juniper, the latter interpreted to indicate amelioration of climate, i.e. interstadial. It is claimed (Vishnu-Mittre & Bhattacharyya, 1980, 1983) that more than five periods of amelioration of climate had occurred during the last glaciation. There was one before 40,000 years ago. The one between 28,000- and 34,000 years ago is also supported by a biogenic deposit in the profile. It seems to be a distinct interstadial comparable with Denekamp in Europe. The interstadial between 21,000 and 18,000 years ago indicates deglaciation at this time or slightly after. Among the others recognized are between 17,000 and 16,000 radiocarbon years and at 10,000 radiocarbon years. Between 15,800 and 10,000 years the climate reverted to cold again. Interestingly, close correspondence is observed between these interstadials and some dated palaeosols in the Kashmir Valley (Vishnu-Mittre, 1984; Vishnu-Mittre *et al.*, 1984).

A profile (Text-fig. 6) about 4 km from the subalpine meadow at Toshmaidan has on radiocarbon dating (Singh & Agrawal, 1976) shown that the bottom 3 m were deposited before 15,000 years ago and the top one meter during the Holocene times commencing from 10,000 years ago. An erosional break has been observed in the extreme top above 50 cm as the topmost sample at 15-35 cm is dated to $2,790 \pm 160$ radiocarbon years. Unfortunately this profile has not been pollen analysed in detail. The pollen spectra of the dated samples are related with the pollen stages in pollen diagram from Toshmaidan earlier published and referred to post-glacial (Singh, 1963). Both the stratigraphy and pollen stage correlation in the two profiles leave much to be desired.

The substantial part of the reconstructed Toshmaidan pollen diagram (Text-fig. 6) is dominated by the sedge-chenopod-Compositae steppe, chenopod-*Artemisia*-grass steppe and subsequently by *Artemisia*-grass steppe, and finally sedges predominating above 60 cm to the top. Within this predominant steppe environment there were events of immigration and expansion of trees constituting forest communities. The extrapolation of the radiocarbon dates from the unpollenized profile to this pollen profile would suggest the occurrence of blue pine-deodar community with temporary rise of oaks prior to 15,000 years which seems to indicate a warm oscillation as inferred at slightly before 15,800 years in the Tsokar Lake profile. Within the steppe conditions, the immigration of birch followed by its expansion indicates the commencement and increase in amelioration of climate. Its subsequent expansion and eventual formation of alpine fir-birch forest is seen towards the extreme top of the diagram. The present belt of this forest occurs slightly higher up.

The Haigam pollen diagram from the valley proper (Vishnu-Mittre & Sharma, 1966) reflects $\pm$ similar pattern of change but the alpine constituents are present in extremely poor frequencies. The two radiocarbon dates are much younger (Vishnu-Mittre, 1979). A well-dated sequence needs to be prepared again. However, here too the *Artemisia* steppe conditions dominate nearly three-fourth of the pollen diagram. The abrupt decline of oak mixed wood towards the top is observed in both the Toshmaidan and the Haigam pollen profiles.

Both the pollen diagrams show the occurrence of *Quercus* and *Alnus* in fair to good frequencies declining towards the extreme top. These two genera have long been known to be absent from the valley except the subsequent discovery of stray occurrence of *Quercus dilatata* and *Q. semecarpifolia* (Vishnu-Mittre, 1963). They would, on pollen evidence, appear to be relics of early Quaternary oaks. The occurrence of oaks with *Artemisia* makes a better case for the former occurrence of the dry *Quercus ilex* steppe forest (Champion & Seth, 1968, p. 325), because the precipitation had already become much reduced by the lofty Pir Panjal (Vishnu-Mittre, 1966a, 1974a, 1974b).

At a still lower latitude (about 27° lat.) 7° lower than that of Tsokar, Haigam and Toshmaidan in the western Himalaya and discussed above, the vegetational sequence during the last glaciation in the subtropical Kathmandu Valley, Nepal in the Central Himalaya (Vishnu-Mittre & Sharma, 1984) shows fluctuations between steppe and oak or oak-pine woods. Three interstadials recognized by expansion of oak woods within steppe are dated pre-40,000, 25,000 and 17,000 radiocarbon years more or less corresponding with those in Ladakh. Between 15,000 and 11,000 radiocarbon years open oak or open pine-oak woods had occurred. Both natural pine and oak woods are nonexistent in the valley today. However, they occur in the surrounding mountains under much higher precipitation.

In keeping with the Code of Stratigraphical Nomenclature of India, the last Glaciation in the Himalaya should be named as Tsokarian after the Tsokar Lake profile. The interstadials can be named subsequently after more information is gathered.

About 5 m deep marginal profile from Naukuchiya Tal not far from Nainital in the Kumaon Himalaya (Vishnu-Mittre *et al.*, 1967; Gupta, 1977) has an undated pollen profile where the chirpine woods were gradually invaded by oak mixed woods and these eventually dominated the remaining pollen diagram to its extreme top. The sequence seems to cover a large part of the postglacial, here commencing most likely from about or before 8,000 years ago. Recent brief report reveals it to be before 8,000 radiocarbon years (Khandelwal & Gupta, 1983). The Sat Tal pollen sequence in the same region is much later and shows predominance of pine over oaks until 1,400 radiocarbon years when oaks predominated over pines and the re-expansion of oaks took place again in the late 19th century (Gupta & Khandelwal, 1982b).

The pollen sequences from Himachal Pradesh show dense oak woods dominating the region since about 4,000 years ago. They were replaced by *Cedrus* (Deodar) woods in Khajiar by about 1,250 years ago whereas at Rewalsar their replacement by chirpine commenced about 1,400 years ago and completed by about 500 years ago (Sharma & Singh, 1974). The floating islands in these lakes began forming by about 700 A.D. (Sharma, 1972). It is not certain if this change may be attributed to a change in climate or to anthropogenous influence destroying the oak woods thus allowing the light demander chirpine or deodar to replace them. The stumps of oaks in these forests are still reminiscent of not only their former occurrence but dominance also.

The pattern of vegetational change in the immediate past in the Kashmir Valley (Singh, 1963) is observed in two shallow and undated profiles. The shallow profile (70 cm) from Braman Mire-B shows predominance of blue pine with high frequencies of grasses and other herbs and *Abies* showing rising trend. The large-sized grass pollen grains are identified as of *Zea*. The deeper (120 cm) profile from Walanwar shows consistently high frequencies of grasses and other herbs and those of *Zea* consistently rising. The pollen of *Zea*, if correctly identified, would date the diagram from about 1,500 years A.D. Against the high values of non-arboreals those of pine pollen may be misleading. The modern pollen spectra do, however, show high pine values but with poor grass pollen frequency. At present the population of blue pine in the valley is extremely poor except along the surrounding slopes of Pir Panjal or Himalayan mountain, and there is intense grazing pressure on the ground vegetation besides cultivation in the valley. The decline of oaks in the valley, as the pollen evidence suggests, took place within the last about 500 years.

From within the mid-altitude about 2,500-2,700 m in the Kashmir Valley, the two shallow profiles namely the Yus Maidan profile from the famous meadow surrounded by pine-fir forest (Pine 70%, Fir 20%, Spruce 5%) and the Baba Rishi profile from within fir-pine forest with stands of *Taxus baccata* show the history of these forests in the immediate past (Sharma & Vishnu-Mittre, 1969). The Yus Maidan formerly extended over much vaster area and the forests now surrounding it and comprising blue pine-fir and spruce had gradually encroached upon the Maidan. Birch was a conspicuous member leading eventually to the blue pine-fir-spruce forest whereas at Baba Rishi the blue pine-fir forest has continued to exist here with gradually increasing proportion of *Abies* and spruce. A feature of great interest is observed in the lower two-third of both these pollen diagrams where fir pollen curve shows decline and then rise at both the sites about 48 km apart. This has been attributed to exploitation of fir for timber in the recent past. This selective extraction of fir seems to induce rise in blue pine in the Baba Rishi profile, and of birch followed by blue pine in the Yus Maidan profile. Fir is largely used for matches, wood pulp, timber and for firewood.

In addition to the above, the recent brief reports (Dodia *et al.*, **1982b**, 1982c) show the continued dominance of *Pinus wallichiana* since 15,000 years ago in the vicinity of Botapathri, since 4,000 years ago in the vicinity of Anchar Lake and since 1,000 years ago in the vicinity of Hokar Sar in the Kashmir Valley. However, the detailed results must be awaited on these unusual features, and any comments are reserved till then.

The small sequence from Bhim Tal (Gupta, 1977) likewise portrays recent developments of vegetation in the vicinity of this lake in Kumaon Himalaya.

The predominance of Chirpine pollen in a clay sample from Kalidhang, District Sirmur, Himachal Pradesh has led Tewari *et al.* (1979a) to infer the former occurrence of *Pinus roxburghii* forest. Pine pollen grains are capable of misleading for their former occurrence and this fact is well known in most parts of the world and in the Himalaya. From the same deposit Tewari *et al.* (1979b) have described some leaf impressions — a mixture of temperate and subtropical species (*Prunus* sp., *Mallotus philippensis* and *Celtis* sp.). Diatoms such as *Melosira granulata, Rhoicosphenia curvata* and *Pinnularia gibba* are also reported from here (Swain, 1982).

The only information from Assam comprises two pollen spectra from near Tockalai Experimental Station, Cinnamara indicating fluctuations in the open *Ardisia-Eurya-Dillenia*-oak forest unsupported by modern pollen/vegetation relationships (Gupta, 1971).

Information on macrofossils has also been brought out by pollen analyses. The seeds and fruits from the postglacial deposits from Kumaon (Gupta, 1973) remain to be properly identified and evaluated from the climatic and phytogeographical viewpoints (Vishnu-Mittre, 1974a, p. 24), but the evidence of the former occurrence of mosses more particularly of sphagna in the subtropical belt and some hitherto unreported from the western Himalaya is an invaluable contribution to Indian phytogeography (Singh, 1963; Vishnu-Mittre & Gupta, 1971; Sharma, 1976).

Land Use

The impact of early man and his grazing animals upon vegetation in the Himalaya has also been inferred from the pollen diagrams. The selective use of fir at Baba Rishi and Yus Maidan (Sharma & Vishnu-Mittre, 1969); of *Celtis* in Kumaon (Vishnu-Mittre, Gupta & Robert, 1967; Gupta, 1977); overall change of oak woods into pine or deodar woods in Himachal Pradesh (Sharma & Singh, 1974); the extinction of oaks and alders in the Kashmir Valley and the poor values of grasses in Kashmir pollen diagrams attributed to intensive activity of grazing animals (Vishnu-Mittre, 1966; Vishnu-Mittre & Sharma, 1966) are some of the examples. Besides the exploitation of wild plant life, the event of commencement and progressive increase in land use by man through recognition of cereal pollen and weeds of cultivation and through fluctuations in pollen curves indicating decline and recovery of forest in response to clearance, farming and abandonment of the sites has been inferred in specially computed pollen diagrams (Vishnu-Mittre & Sharma, 1966; Gupta, 1977). In one instance evidence of charcoal has also been found, whether it is natural or man-made remains to be known (Vishnu-Mittre, *et al.*, 1967; Gupta, 1977).

The recent radiocarbon assay dates some events of land use much beyond the known estimates for the Neolithic period in the Himalaya. The discovery that very large grass pollen comparable with that of any known cereal is also produced by wild grasses in India, and some of these are also distributed in the Himalaya (Vishnu-Mittre, 1973b) suggests that the inference of land use from pollen diagrams based upon this criterion requires more dependable and indisputable evidence. Further, it is important that the significance of the alterations in vegetational development inferred to suggest that the past land use must be carefully understood. That these might have been caused by factors other than human influence must not be overlooked (Vishnu-Mittre, 1980).

The undisputed evidence for the past land use indeed can be provided by the remains of cultivars discovered from well-dated archaeological sites. And this parameter has shown recently that the land use in the Indian subcontinent had commenced some thousands of years before the hitherto dated Neolithic, that is at the beginning or soon after the Holocene period (Vishnu-Mittre, 1976; Jarrige, 1982). The dependable support for the same from pollen evidence may await till the distinction between the fossil and the extant cereal and grass pollen has been demonstrated by the sophisticated methods known today.

Against the pollen evidence for land use by man and exploitation of wild plant life by man and his grazing animals may be mentioned the macrofossil evidence discovered from the archaeological sites in the Himalaya. The evidence of seeds of wild plants and forage crops (*Lithospermum arvense*, species of *Ipomoea*, and of several wild legumes: Vishnu-Mittre, 1966b) from the Neolithic site Burzahom about 6 km north-east of Srinagar in the Kashmir Valley and dating from 4,300 radiocarbon years (Agrawal & Kusumgar, 1965) shows that the Neolithic Burzahomians were possibly food gatherers. These weeds and forage crops also occur in the wheat and barley fields. That these two crops were grown in the valley becomes evident nearly 300 radiocarbon years later at the site Gufkral about 41 km south-east of Srinagar (Sharma, A. K., 1979-80). Besides, wheat (*Triticum*) economy at this site had also included lentil (*Lens culinaris*) and *Pisum arvense*. This food economy at this site had continued until towards the end of the Megalithic period, when rice (*Oryza sativa*) and Ragi (*Eleusine coracana*) were introduced in the valley.

From 1,500 B.C. to 2nd cent. B.C., the food economy at yet another site Semthan in the Kashmir Valley comprised wheat (*Triticum compactum & T. sphaerococcum*), barley (*Hordeum vulgare*) and rice (*Oryza sativa*). Together with these were found seeds of forage crops *Vicia sativa*, species of *Trifolium* and *Medicago* and *Avena fatua* (Buth *et al.*, 1982).

The continuation of more or less the same weeds and forage crops from 4,300 radiocarbon years till early historical times and the introduction of farming nearly 300 years later seems to suggest the continuation of food gathering even after the introduction of farming. What for these weeds and forage crops were gathered and used remains unknown. A very significant feature brought out by these discoveries is that rice, the present staple crop in the valley, was introduced in wheat-barley based economy about 900 years later. That Ragi was introduced later to rice is also interesting as it is grown in the Himalaya today and perhaps not in the Kashmir Valley.

The evidence of rice cultivation from other parts of western Himalaya (site Kalsi in Dehradun and from sites in Assam: Vishnu-Mittre, unpublished) is much later than records in the Kashmir Valley. With considerable diversity in progenitors of rice in Assam, it is hoped that this potential region in the Himalaya may yield the oldest records of rice cultivation in the Himalaya.

The exploitation of forest trees by the Neolithic peoples at Burzahom and Gufkral nearly 47 km apart from one another shows a progressive and selective use of the forest trees but the kinds of trees used at these two sites were not the same. Whereas timber of *Cedrus deodara*, *Parrotia jacquimontiana* and species of *Celtis*, *Ulmus* and *Pinus* (Savithri, 1976) was used by the Neolithic Burzahomians; the Neolithic Gufkralians had used timber of *Pinus* sp. during the Aceramic period, of *Juglans regia*, *Aesculus indica* and species of *Pinus* and *Prunus* during the Early Neolithic and of *Ulmus wallichiana*, *Buxus wallichiana* and species of *Picea* and *Pinus* during the late Neolithic (Vishnu-Mittre & Chanchala, 1983).

Around the Christian era timber of *Shorea robusta*, *Mangifera indica* and species of *Terminalia* and *Cinnamomum* were exploited by the people at the site Kalsi in Dehradun (Ghosh & Lal, 1961; cf. Vishnu-Mittre, 1974a, 1974b). No information is available from the central and eastern Himalaya of the exploitation of forest wealth.

CONCLUSION

Overviewing the entire available mass of palaeobotanical/palynological information from the Himalaya, it would be admitted that this botanical parameter hardly shares any iota of credit for delimitation of the Neogene/Quaternary boundary and likewise the Pleistocene/Holocene boundary. On the other hand the entire credit in the potential area of the Lower Karewas in the Kashmir Valley goes to preliminary palaeomagnetic studies and to, howsoever insufficient, fission track dating (Burbank & Johnson, 1982). The palaeobotanical/palynological evidence would have us believe that the Pliocene floristics were much like the early Pleistocene floristics, and there is hardly anything like the transition from the one into the other. The boundary could have been recognized at this botanical transition.

An overview of the Miocene-Pliocene floristics in the Siwaliks (Vishnu-Mittre, 1984) reveals that a remarkable change is discernible from wet tropical evergreen forests in the Miocene to floristics indicating moist conditions in the Pliocene and comprising members of Cyathaeaceae, Parkeriaceae, Schizaeaceae along with species of *Podocarpus*, *Pinus*, *Cedrus*, *Magnolia* with an inaperturate pollen type referred to the form genus *Laricoidites* (believed to be comparable with the pollen of *Larix*) predominating on which tropical to temperate, temperate to subtemperate climatic conditions have been inferred (Singh, 1982; Saxena & Singh, 1982). However, the temperate climate did exist in the Miocene period at altitude higher than that of the then Siwaliks as inferred from the recent discovery of palms of Chinese-Russian taxa in the Liyan Formation of Ladakh (Lakhanpal *et al.*, 1983; Vishnu-Mittre, 1984).

The utter absence of the Siwalik Pliocene flora complex referred to above in the corresponding Lower Karewa exposures in the Kashmir Valley but for pollen grains of *Cedrus*, *Pinus* and *Larix* type deserves serious consideration from biogeographical viewpoint. Nevertheless as many as 15 climatic oscillations, tropical, subtropical, temperate and cold (alpine), are briefly reported by Gupta *et al.* (1982b) which in fact are not borne out by the reported pollen assemblages. Further, each lithotype without regard to its position in the section has been found to be characterized by the same pollen assemblage and the alterations between temperate and subtropical floristics makes the entire information highly confounding. However, the publication of full information is eagerly awaited. At the present state it would seem that this confusion may be attributed to insecure identifications, utter disregard of sedimentation/preservation phenomena and ignorance of the ecological and distributional perspectives of the taxa identified.

Besides a sound knowledge of the ecology and distribution pattern of the extant taxa in the Himalaya, well-established determinations of their remains, a good conversance with the role of dispersal, sedimentation and preservation and the rate of sedimentation are imperative in achieving the objectives through the application of pollen analysis. The identification of plant remains with published figures and photographs from other parts of the world (Gupta, 1973), the interpretation of composition of the present forest communities from modern pollen spectra from within them (Gupta, 1977), and describing occupation phase in lower part of a pollen diagram and the Landnam phase in the upper part of the same (Gupta & Khandelwal, 1982) without realising that they mean the same, and inferring from *Artemisia*-cheno-ams-grass-sedge assemblage from Lower Karewas vegetation of the type that exists today in Ladakh 5,000 m above sea level (Dodia *et al.*, 1982a) suggest utter lack of understanding the methodology of Quaternary palynology, of ecology and distribution of plant life in the Himalaya, and the tendency to jump to conclusion.

The *Artemisia* - cheno - ams - grass-sedge assemblage could indicate an environment approximating the one in the Pishin Valley (1,375-1,600 m) near Queta for the same altitude as of the Lower Karewas at present or the environment above tree limit and below the glacier at 2,800 m at Tilel or below the snowmelt alpine region in Baluchistan (Stewart, 1982) if believed that the Lower Karewa deposits were laid at altitude higher than that at present.

The abominable mystery of *Laricoid*, *Larix*-like or *Larix* pollen from the Pliocene to recent requires special attention towards the solution of this mystery, more particularly in the light of its restricted distribution in the central and eastern Himalaya where it occurs in the fringe near the timberline in the upper part of high level conifer forest with *Abies spectabilis* and *Betula utilis* with shrubs of the species — *Rosa macrophylla*, *Berberis aristata*, *Cotoneaster rotundifolia* and *Rhododendron campanulatum* between 3,000 and 3,500 m a.s.l. in the Buri Gandak Basin in Nepal (Kitamura, 1955). More or less at the same altitude and ascending slightly higher, it occurs along with *Picea morinda* and *Tsuga brunoniana* in the humid mountains of the Lachung Valley in Sikkim (Gammie, 1894) and in the Zemu Valley at about, 3,000 m alongwith *Picea*, *Tsuga*, *Abies*, *Juniperus* associated with species of *Berberis*, *Ilex*, *Euonymus*, *Acer*, *Rubus*, *Rosa*, *Rhododendron*, *Betula*, *Alnus* (Smith & Cave, 1911) and again above 3,000 m in the Mishmi hills in North-East Frontier Agency associated with mixed conifer forests (Bor, 1938). Believed to be edaphic or pioneer, *Larix* occurs in an environment which may be described subalpine though Champion and Seth (1968) mention the Larch forest among the temperate forest types. It is nowhere associated with *Pinus roxburghii*, as observed in Holocene pollen diagrams from the subtropical regions of Kumaon and Himachal Pradesh along with pollen of subtropical pines and oaks (Gupta & Khandelwal, 1982b; Sharma & Singh, 1974). In the light of its environment discussed above *Larix* should not be considered to have been a member of subtropical forests during the postglacial times. The continuous recovery of its pollen from Pliocene until recent times in the Himalaya may suggest that it was either widely distributed in the past or it is a high pollen producer with a capability of wide dispersal. Has its pollen been distinguished beyond doubt is another question that needs a definite answer ? Likewise there is a case of definite distinction of pollen grains of *Pinus roxburghii* from those of *P. wallichiana*. It is therefore all the more important that fresh and copious materials of pollen grains of himalayan conifers collected from the length and breadth of the Himalaya are examined again to solve the abominable mystery of *Larix*-like pollen and similar problems concerning other conifers.

The present day Himalayan flora is made up of taxa of diverse geographical origins: Irano-Turanian, Saharo-Sindhian, Sino-Japanese, Mediterranean and tropical to name some important geographical units. Barring a small percentage, many species are endemic. When and underwhat circumstances (climatic, edaphic or biotic) these diverse plant geographic units entered the Himalaya ? What were the floristics which were replaced by them ? When and under what circumstances the immigrating foreign species reaclimatized and endemized ? What were the indigenous tropical taxa that have continued and escaped the repeated and drastic changes in climate and how many were decimated ? It is a huge task for the Quaternary pollen analyst to find answers to these questions. This overview finds that hardly any attempt has been made to answer any of these questions. This is a very rich area of biogeographical enquiry and pollen analysis can alone provide a factual history through mapping the distribution in time and space of the Himalayan taxa.

There can be no denying that the plant species subjected to successive climatic and edaphic alterations during the Quaternary period must have been compelled to acquire climatic requirements different from those when they had entered the Himalaya, otherwise they could not have survived. The instances of ecologically incompatible taxa among those identified Lower Karewa plant remains discussed elsewhere in the text is a testimony to the concept that the past is the key to the present but the present cannot be ignored because this provides the comparable floristic complex in the Himalaya comprising considerable phytogeographical diversity and therefore it deserves a serious attention.

The occurrence of some himalayan plant species in the hills of Madhya Pradesh (Pachmarhi), Bihar (Parasnath) and Rajasthan (Mt. Abu) where the peaks are about 1,200-1,350 m a.s.l. and in the south Indian mountains (Nilgiris, Pulneys) where the peaks are over 2,000 m has remained an abominable mystery in Indian phytogeography. Even though constituting a small percentage, this himalayan floristic element in the hills of central and south India has long been attributed to the impact of glaciation in the Himalaya which forced these species to migrate southwards.

The climatic fluctuations during the last glaciation in the trans-himalayan to subtropical regions of western and central Himalaya as discussed elsewhere in this paper were not strong enough to cause migration of the trans-himalayan floristics into the subtropical region of the Himalaya. What were the conditions during the previous glaciations are still unknown.

Interestingly, the climatic oscillations during the last glaciation in the Himalaya and those during this period in the Nilgiris have been found to be largely synchronous (Vishnu-Mittre, 1983; Vishnu-Mittre *et al.*, 1984). Thus, the theory that the himalayan floristic elements migrated southwardsduring glaciation is not borne out by the present state of knowledge.

There are on record recently discovered instances of occurrence of plants of one region into the other. The west himalayan *Oxybaphus himalaicus* has been recorded recently at the foot-hills of Chamundi Hills in Mysore (Rao & Razi, 1975); *Solanum khasianum* Clarke var. *Chatterjeeanum* of Assam, Burma, Bengal, Orissa, Madras has been recently reported in Dehradun in western Himalaya (Bahadur & Dayal, 1968); the east Himalayan orchid *Tropidia curculigoides* has also been reported in Dehradun (Deva & Arora, 1971); *Helminthostachys zeylanica* of South India, Assam and Bengal has been recently recorded from Lakshmipur forests in Gorakhpur (Dikshit & Tripathi, 1966). To which climatic oscillations in the recent times the migration of these and such other examples reported from the peninsular south to Himalaya and from the east to the west of the Himalaya and vice-versa may be attributed?

The parameters other than climate for the dispersal and distribution of plant species from one climatic regime to another must be considered. Among these the role of avefauna (Ali, 1981) deserves special mention in this context. There are quite a few himalayan relicts in the avefauna in the Western Ghats complex, for instance, the Laughing Thrushes (*Garulax*) of Indo-chinese origin, the Great Hornbill (*Buceros bicornis*), the Frogmouths (*Batra chostomus*) and species of *Irena*, *Aviceda* and several others. The subspecies of these relicts are now recognized in the Nilgiris and these are considered to be endemic. The species of *Garulax* particularly are closely associated with species of *Rubus* both in the Himalaya and Nilgiris and they occur at the same altitudinal range about 1,000 m or above (Ali, 1981).

Even some birds endemic in Himalaya fly nonstop 1,500-2,000 km each way to hills in South India such as the Woodcock (*Scolopax masticola*), the Pied Ground Thrush (*Zoothera wardii*), the Blue Chat (*Erithacus brunneus*), etc. Their halts in between hills are seldom observed. From the normal flight of 60-80 km per hour, they reach the Nilgiri and Pulney mountains in about 25 hours. The seeds of many plant species retain the viability during this interval of time.

It appears that the solution to the abominable mystery in Indian phytogeography referred to above lies in the role of avifauna rather in the impact of himalayan glaciation(s).

The importance of the immediate antecedents of present forest communities from pollen analysis of shallow profiles in the understanding of events in the immediate past particularly for a larger understanding of the factors which governed distribution of past plant life does not need emphasis. It is encouraging that some work as discussed elsewhere in the text has already been done. It is this area of research which needs more attention but it must be accompanied by ecological studies of present day communities surrounding the shallow swamps and marshes. The Muthronwala swamp about 15 km south-east of Dehradun in the western Himalaya is a typical example where both pollen analytic and ecological work has been done. The great botanical potential of the forest in this swamp was reported by Kanjilal in 1901 recording *Quercus incana*, *Olea glandulifera*, *Acer oblongum*, etc. at this swamp at 600 m, much below their normal occurrence between 1,000 and 2,500 m. The ecological studies at this swamp by Deva and Aswal (1974) have revealed the absence here today of *Pittosporum rawalpindiense*, *Pterospermum acerifolium*, *Itea nutans*, *Hedera nepalense*, *Symplocos crataegoides*, *Linociera intermedia*, *Holostemma annulare*, *Persea duthiei*, *Neolitsea cuipala*, *Helixanthera ligustrina*, *Celtis australis*, *Ficus glaberrima*, *Albizia chinensis* which were recorded by Kanjilal (1901) about 73 years before. The stumps of *Acronychia pedunculata*, *Acer oblongum*, *Sabia paniculata*, *Olea glandulifera*, *Persea gamblii*, *Elaegnus conferta*, *Drypetes assamica* and *Quercus incana* in the swamp forest reveal their former occurrence as reported by Kanjilal (1901).

The pollen analysis of a 1.65 m profile from the swamp (Rawat, 1982) shows a well-developed forest complex which declined subsequently after 500 years ago. No evidence of change in climate has been observed in the pollen sequence. The pollen analysis brings out the evidence for the occurrence of *Pterospermum*, *Acronychia*, *Acer*, *Itea*, *Symplocos*, *Albizia*, *Ficus*, *Elaegnus*, *Olea*, *Quercus* and members of Lauraceae. The stumps of some of them occur in this swamp forest.

It is indeed interesting that the floristic development in the Himalaya, as the pollen analytical studies have revealed, has exhibited broadly more or less similar pattern as has been observed during the Quaternary period in temperate and alpine regions in other parts of the world. It is further interesting that some of the climatic fluctuations inferred from the patterns of vegetational development more particularly during the last glaciation to recent synchronize those elsewhere supporting their secular nature. There is need to construct several more pollen diagrams supported by well-determined isotopic dates to establish the global and local climates in the past. The indigenous ecological perspective, and a good understanding of the phenomena of production, dissemination and preservation of pollen/spores is highly important in achieving this objective. Any disregard of these is certain to result in misleading and confusing interpretations, examples of which have been pointed out elsewhere in the text.

tropical, temperate, alpine, and in the trans-himalayan regions of the Himalaya differ today from one another so these must have in the past. The climatic inferences would be more secure if this fact is realized pollen analytically also. The same may be said of the patterns of forest development in these latitudinal belts. From the present day distribution of forest types within these latitudes schemes for probable forest development in response to climatic fluctuations can be constructed which should help in translating the pollen sequences in terms of vegetation and climate.

An example of such a scheme for the temperate belt in western Himalaya is given below which gives development of vegetation between two cold oscillations (glaciations).

COLD	STEPPE	CRYOCRATIC
Post temperate	*Abies*, *Betula*, *Pinus* with or without *Sorbus*, *Larix* and *Quercus*	Telocratic
Late temperate	Mixed conifer-oak mixed forest with *Alnus*, *Corylus* and *Acer*	Oligocratic
Early temperate	Mixed oak forest with *Ulmus*, *Juglans*, *Fraxinus* and *Corylus*	Mesocratic
Pretemperate	*Abies*, *Betula*, *Pinus* with or without *Sorbus*, *Larix* and *Quercus*	Protocratic
COLD	STEPPE	CRYOCRATIC

There is no denying that information on development of forest communities at the same latitude in the Himalaya in response to climatic alterations and edaphic changes is not available. However, climatic gradients are discernible from the forest belts distributed altitudinally. These belts must have ascended or descended in the past in response to climatic oscillations. Extensive work is needed to bring out this important aspect of biogeography.

The mass of pollen analytical data has indeed given some indications of the kinds of plant life that had characterized the Glacial and Interglacial periods, and the stadials and interstadials. Extensive work is needed to establish this — the botanical criteria for recognition of these stages and to distinguish the warmer and cooler fluctuations in latitudinal belts. They may not be similar in all latitudes in the Himalaya. The steppe vegetation types in the sub-

A similar postulated scheme workable for the eastern Himalaya should include *Tsuga*, *Eurya*, *Pittosporum*, *Magnolia*, *Acer*, etc. in the temperate stages.

An interstadial (temporary warm fluctuation within a glacial) may be recognized by Juniper scrub, *Betula-Salix*, *Betula-Sorbus-Quercus semecarpifolia-Lonicera* or *Rhododendron*.

Similar schemes can be drawn up for the subtropical and alpine belts to serve as guide lines and to see if the factual patterns of floristic development from pollen analytic work confirm or modify these. It is through such schemes that not only the interpretation of pollen profiles is fascilitated, correlations can be securely established and the behaviour of the immigrating taxa can also be made out.

It is highly important that glacial/interglacial, stadial/interstadial stages in the Himalaya are named after type sites in keeping with international practice. Some names are suggested in the text. Detailed work is needed to achieve this objective.

Encouraging results have been obtained concerning the origin and progressive expansion of land use, and progressive and selective exploitation of the himalayan forests. This important area needs further research to bring out the manner and the rate at which some himalayan ranges have been denuded of forests, and where the forests exist they have been physiognomically altered through selective exploitation. May be the studies suggest measures for the reclaimation and conservation of the remnant forest wealth in the Himalaya. Likewise the work on past climates should be understood to predict the climatic trends in the future.

Finally to sophisticate the pollen analytical technology in achieving these objectives in the Himalaya and elsewhere in the country, this overview urges the Indian pollen analysts to adopt the current approaches such as total influx of pollen and rate of sedimentation, numerical methods, etc. to impart a new dimension to the techniques hitherto followed so that the results obtained become more dependable for flora history and for inference of past climates. Attention to these has been drawn earlier (Vishnu-Mittre, 1978).

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