Changing pattern of vegetation in the intermontane basin of Kashmir since 4 Ma : a palynological approach

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Gupta HP 1992. Changing pattern of vegetation in the intermontane basin of Kashmir since 4 Ma : a palynological approach. *Palaeobotanist* **40** : 354-373.

The Upper Karewas are devoid of biomass potential and hence no palynostratigraphy could be established. In contrast, Lower Karewas are both quantitatively and qualitatively rich in biota. The major areas of study include Dubjan, Hirpur, Krachipathra, Ningle Nullah, Laredura, Liddarmarg, Butapathri, Wapjan, etc. Dubjan, supposedly the basal part of the Karewa sequence, overlies unconformably the Panjal volcanics and Hirpur overlies the Dubjan. Recent palaeomagnetic studies suggest that these sediments span late Gilbert to middle Matuyama magnetic polarity ranging in age between 3.5 to 2.0 Ma. Wapjan is the uppermost part of the Lower Karewa and falls between late Matuyama to early Bruhnes ranging in age between 0.75 to 0.70 Ma.

Palynological and palaeobotanical investigations carried over a large number of exposures have revealed that there is no unanimity in vegetation all through the Karewa deposits, instead a variety of vegetation type has been recorded in time and space indicating their development under different circumstances. The vegetation met here varies from typical subtropical to desertic alpine type. The climate has not been static for a long period rather reciprocity in the climate has been recorded which has been deciphered from vegetal signatures left by the nature. Post-glacial sediments from the lake basin in the valley have also been investigated, which reveal three-fold vegetational development reflecting on three-fold climatic evolution.

Key-words—Palynology, Palaeoclimate, Vegetation, Intermontane Basin, Karewa, Kashmir.

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साराँश

पिछले 40 लाख वर्ष में कश्मीर की अन्तरपर्वतीय द्रोणी में बदलती वनस्पति : परागाणविक दृष्टिकोण

हरीपाल गुप्ता

उपरि करेवा में जैवद्रव्य न मिलने के कारण यहाँ की परागाणुस्तरिकी अन्वेषित नहीं की जा सकी और इसके विपरीत अधरि करेवा परिमाणात्मक एवं गुणात्मक दृष्टि से जीविता से भरपूर है। दुबजन, हीरपुर, कराचीपथरा, निंगल नाला, लरेड्रा, लिडरमार्ग, बूटापथरी, वापजन इत्यादि नामक मुख्य अध्ययन किये गये क्षेत्र हैं। ये सम्भवतः करेवा अनुक्रम के आधारी भाग हैं तथा पंजाल ज्वालामुखी ऊपर परन्तु असम्बद्ध स्थित है, हीरपुर दुबजन के ऊपर स्थित है। अभी हाल में पुराचुम्बकीय अध्ययन से प्रस्तावित होता है कि ये अवसाद अर्नतिम गिल्बर्ट से मध्य मातुयामा चुम्बकीय ध्रुवता तक विस्तृत हैं तथा 30 से 20 लाख वर्ष आयु के हैं। अधरि करेवा का ऊपरी भाग वापजन कहलाता है तथा अर्नतिम मातुयामा से प्रारम्भिक ब्रुहनेस तक विस्तृत हैं और 75,000 से 70,000 वर्ष आयु के हैं।

अनेक अनावरणों के परागाणविक एवं पुरावनस्पतिक अध्ययन से व्यक्त होता है कि यहां की वनस्पति में समांगता नहीं है जिससे यह व्यक्त होता है कि इनका विकास विभिन्न परिस्थितियों में हुआ है। यहाँ मिलने वाली वनस्पति सामान्य उपोष्ण कटिबन्धीय से शुष्क अॅल्पीय प्रकार की है उपलब्ध आँकड़ों से यह व्यक्त होता है कि यहाँ की वनस्पति में जल्दी-जल्दी परिवर्तन हुए हैं। झील के पश्चहिमानी अवसादों के अध्ययन से वनस्पति की तीन पुनरावृत्तियाँ इंगित होती हैं और इसी प्रकार जलवायु की भी।

PAST forty years, especially the preceding two decades, have witnessed a phenomenal progress in the development of science of palaeobotany and palynology in India. Palynologists have played an important role in resolving many a vexed problems related to various aspects of botany and geology.

An article published in May, 1936 on the occurrence of prehistoric lake with abundance of fossil plants at a height of 3,400 m just above Gulmarg (Stewart, 1936), had drawn the attention of Sahni (1936) to explain the significance of these

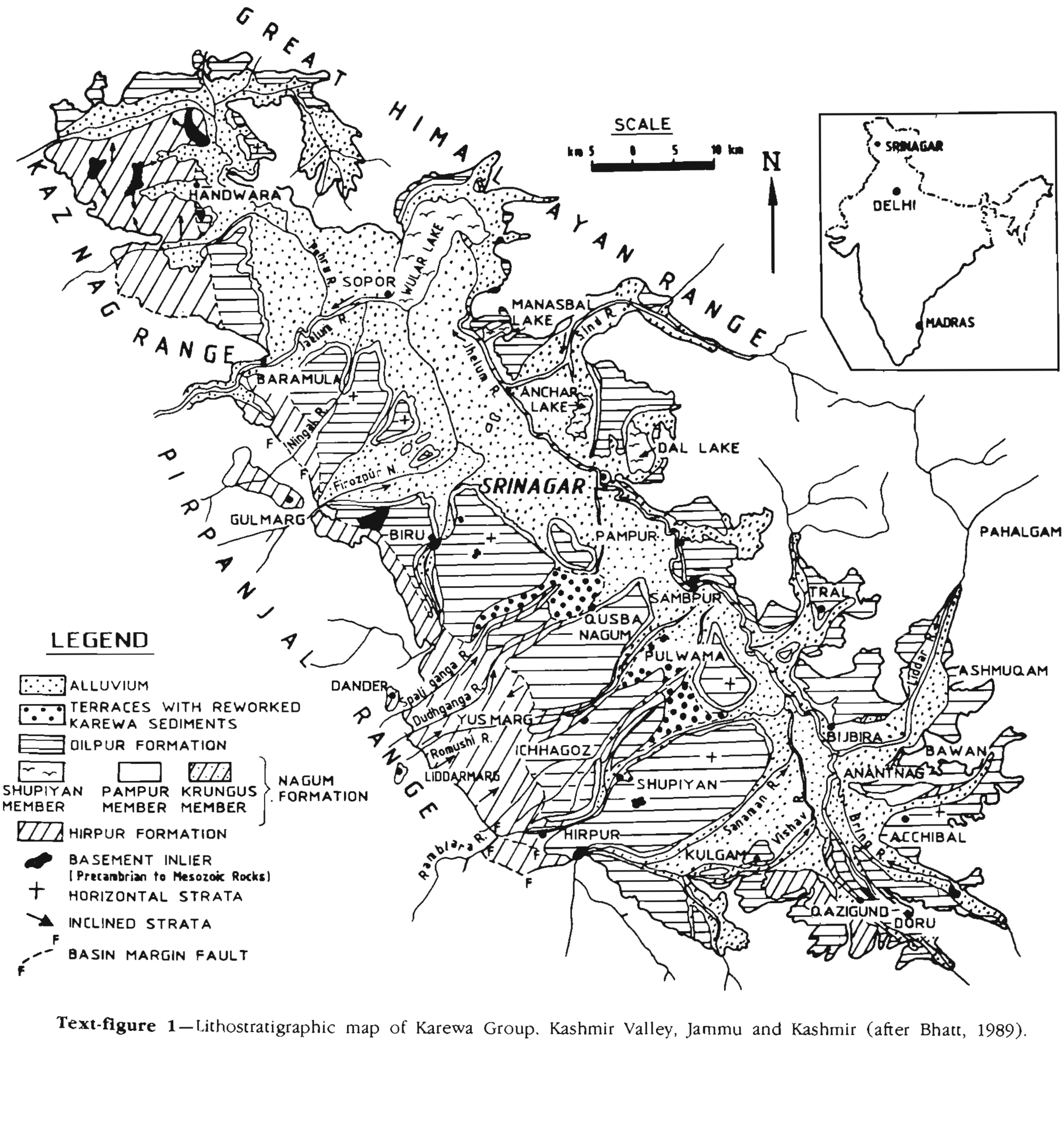
Four Decades of Indian Palaeobotany
Editors : B. S. Venkatachala & H. P. Singh
Publisher : Birbal Sahni Institute of Palaeobotany, Lucknow

deposits at high level known as the Karewa Series.

Recently these Karewa deposits have been traced and mapped as far as the crest of Pir Panjal range which bounds the Kashmir Valley on the south-west (Bhatt, 1989).

Kashmir Valley is an intermontane fault basin and lies between Pir Panjal and the Great Himalayan ranges (Text-figure 1). The Pir Panjal range attains an elevation of about 4,000 m and the Great Himalayan range about 6,000 m. The minimum and maximum elevations in the valley are 1,500 m and 2,200 m respectively. This difference of elevation is evenly distributed through numerous Karewa terraces. Lakes and swamps occupy much of the north-western part of the valley. The lakes, Wular, Manasbal, Anchar, Dal, etc. lie in the flood plain of Jhelum River whose broad meanders have cut swampy lowlands out of the Karewa terraces (de Terra & Paterson, 1939). Some of the above mentioned lakes have been radiocarbon dated and mostly represent deglacial, Holocene or parts thereof. The occurrence of subrecent/recent alluvium is generally restricted to the central portions of the valley. Along the major drainage lines, the alluvial tract extends deep into the Pir Panjal and the Great Himalayan range (Bhatt, 1975).

The fossil bearing sediments near Gulmarg, like many other deposits of clay, sand and gravel on north-east slopes of Pir Panjal were laid down in the lake bed (Stewart, 1936). But, Sahni (1936) did not



Text-figure 1—Lithostratigraphic map of Karewa Group, Kashmir Valley, Jammu and Kashmir (after Bhatt, 1989).

reconcile with Stewart's view point rather opined that the lake never existed at such a high altitude where its bed can be seen today. Strange though it may appear, this lake must have been situated several hundred meters lower than the present main valley level. The sediments have been lifted out of their horizontal position atleast by about 1,500 to 2,000 meters. de Terra (1934) has suggested three orogenies in the region such as Karakoram phase, Sirmurian phase and Siwalikian phase which took place during Middle Cretaceous, Oligocene-Miocene and Late Pliocene-Middle Pleistocene, respectively. He further added that the fourth orogeny took place during middle-Late Pleistocene, which elevated the Pir Panjal. The same orogenic movement lifted the Lower Karewa deposits to the present height of 1,850 m a.s.l.

The study of the fossil plants from the Pir Panjal dates back to 1864 when Godwin-Austen reported the occurrence of fossil leaves belonging to the modern species of plants in clay deposits at Gojipathri near Nilnag and at Liddarmarg, southwest of Gulmarg. Since then fossil plants have been discovered in similar deposits at numerous localities in the Pir Panjal by Middlemiss (1911), Wodehouse (1935) and Puri (1948a, b). The hunt for plant remains is still continuing and a lot of information about the occurrences of fossil plants is pouring in.

The concept that Pir Panjal range is relatively of recent origin was floated by Godwin-Austen (1864) in unmistakable terms. Middlemiss (1911) further supported this idea. de Terra (1933) provided convincing evidence for the same. Sahni (1936) demonstrated that the fossil plants collected from lacustrine beds in the Gulmarg-Baramula region were undoubtedly deposited in the low level lake basin, where the climate was milder.

Similar strata, now tilted at angles as high as 30° to 40° are known to occur in the Pir Panjal range, sometimes at altitudes as high as 4,000 m a.s.l. It is significant that except for some local variations, their dip tends towards the valley and they could be traced downward with gradually decreasing dip into the valley, where they are seen mostly in their undisturbed and almost horizontal position. With this analysis it could be conjectured that at one time Kashmir must have been covered from end to end by the Karewa deposits representing the sediments either of a single vast lake or perhaps a series of water bodies. Thus, the existence of Karewa deposits, as far as the Pir Panjal range, shows beyond doubt that the ancient Karewa lake(s) must have greatly exceeded the present width of the Kashmir Valley.

The nature of stratum, whether clay, sand, lignite, lignitic mud or gravel, its relationship to the underlying/overlying strata, and its fossil contents, if any, indicates as to whether it was deposited in deep water, near shore, stagnant water or stream that fed the lake. Its careful study has led to tangible conclusions regarding the depositional environment and character of the flora and fauna that existed at the time of deposition. Efforts are made to decipher the signatures of vegetal remains from the Kashmir Basin in order to synthesize the data and to reconstruct the vegetation of the past.

GEOLOGY OF KAREWAS

Geology of Karewa deposits in the Kashmir Valley has been a subject of study for more than a century but different views advanced periodically in regards to the origin, nature, stratigraphical status, thickness and the age of these deposits. In the beginning attempts were made to define these deposits in order to establish a stratigraphic base (Godwin-Austen, 1864, 1880; Lyddeker, 1878; Middlemiss, 1911, 1924; Wadia, 1961; Farooqi, 1973; Farooqi & Desai, 1974; Bhatt, 1975, 1976, 1978; Bhatt & Chatterji, 1976). The concept of two-fold classification of Karewa deposits into lower and upper has been in practice since the inception of Karewa. Considering two well-marked regional unconformities, Pal and Srivastava (1982) have suggested three-fold classification into lower, middle and upper Karewas, yet it has not received much attention.

De Terra and Paterson (1939) and Wadia (1938, 1941) opined that the Karewa deposits are of glacial origin. They pleaded that moranic deposits of Glacial Stage I and II resulted into thick conglomerate sequences in the Karewa succession such as Rembiara Member (Hirpur Formation) as I glacial deposit and Suphiyan Member (Nagum Formation) as the II glacial deposit. This view was followed by Bhatt (1975, 1978). Thereafter, the glacial status of Karewa sequence was either prefixed or suffixed with fluvial event. Recent geological and chronological analyses of Karewa sediments have revealed that the conglomerate zones, which were till now considered as marker of I and II glaciers are tectonically generated fluvial sequences (Burbank & Johnson, 1982; Bhatt, 1982a, b). Palaeobotanical and palynological studies conducted over the Karewa sediments have not provided clues for glacial signatures (Puri, 1947; Dodia *et al.*, 1982; Gupta *et al.*, 1984a,b; Gupta & Khandelwal 1987; Gupta & Sharma, 1989; Sharma & Gupta, 1984; Sharma *et al.*, 1984).

Sedimentological data, although meagre, have revealed that the conglomerate beds in the Karewa sequence are perhaps the deposits of pro-glacial braided channels (Tandon, 1981). Tandon *et al.* (1982) have further advocated that the Karewa sediments are largely of fluvio-lacustrine origin. Singh (1982) has provided a conceptual analysis of sedimentation pattern in the Kashmir Basin and has remarked that the deposition took place in a lacustrine basin encompassing the whole Kashmir Valley. In the initial stages the lake was shallow ranging in depth from 5-10 m and later it deepened at several places. He has further emphasized that lithological and sedimentological records do not support the glacial environment for the Karewa deposits. Therefore, Rembiara and Suphiyan members do not show any positive evidence of glaciation and cannot be correlated to either I or II glacial phase respectively.

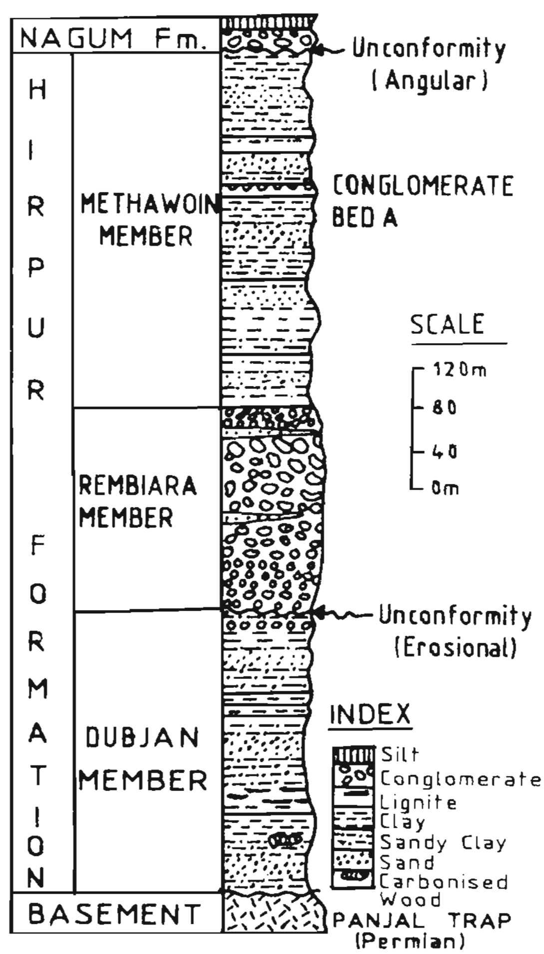
Stratigraphic succession and thickness measurements of the Karewa sequence estimated by various workers are given as follows:

Godwin-Austen (1859, 1864)	130 m
Middlemiss (1924)	1,360 m
de Terra and Paterson (1939)	900 m
Wadia (1961)	1,850-2,175 m
Farooqi and Desai (1974)	1,610 m
Bhatt and Chatterji (1976)	2,755 m
Singh (1982)	1,300 m
Burbank and Johnson (1983)	1,350 m
Pal and Srivastava (1982)	450-500 m
Kaila *et al.* (1984)	1,100 m
Bhatt D.K. (1989)	1,200 m

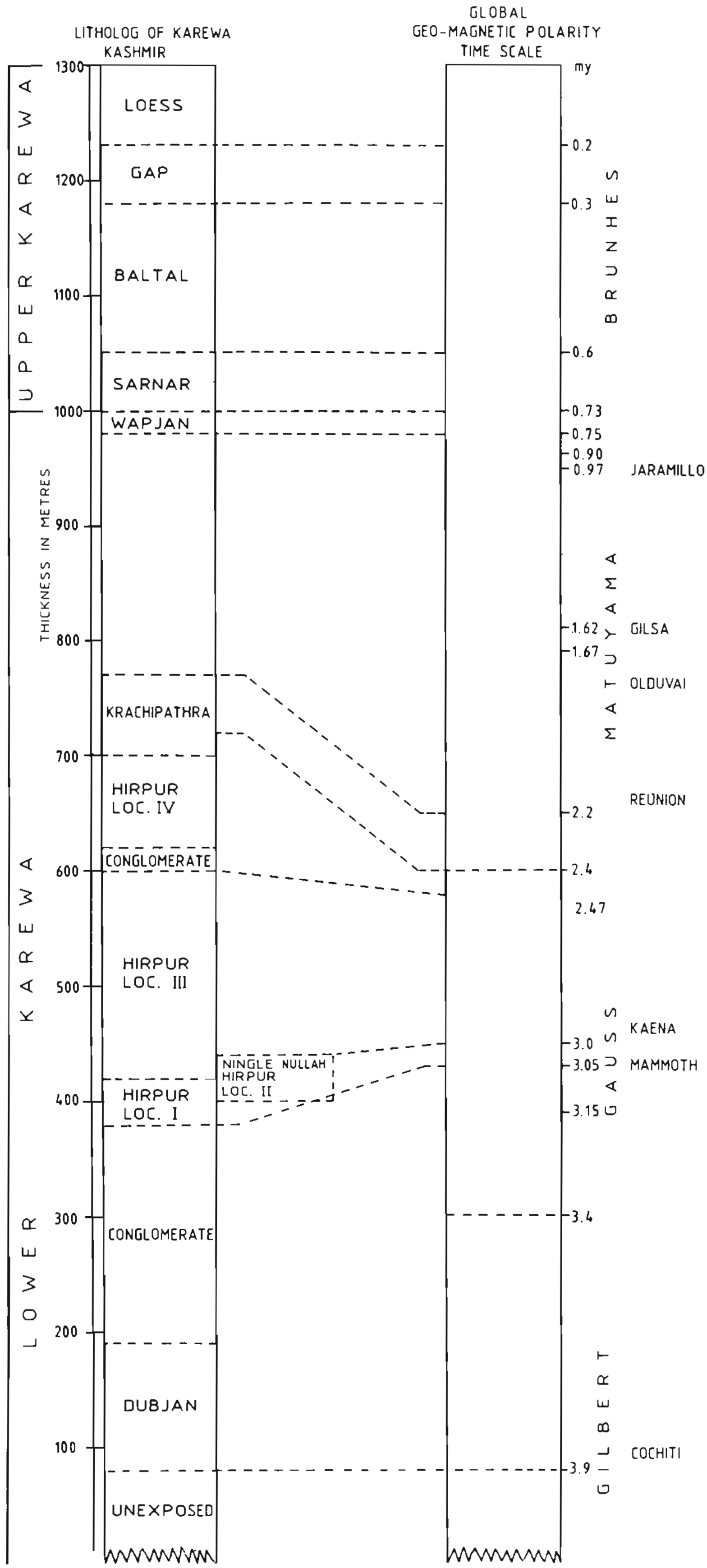
CHRONOLOGY AND AGE OF KAREWAS

Divergent chronologies have been given for the sedimentation in the ancient Karewa Lake/lakes in the Kashmir Valley. Godwin-Austen (1864) referred Karewa deposits to Pleistocene. Lydekker (1883) divided them into lower and upper parts and assigned Pliocene age to the Lower Karewa. Middlemiss (1911, 1924) assigned Plio-Pleistocene age to the Karewas. de Terra and Paterson (1939), on the evidence of *Elephas hysudricus* in the Lower Karewa, assigned a definitive Pleistocene age and correlated them with the Pinjor Stage of the Upper Siwaliks. They worked with the concept of four-fold glaciations and considered Karewa sequence to represent complete cycles of Pleistocene Ice age and correlated Rembiara Member with I glaciation (Lower Pleistocene) and Suphiyan Member with II glaciation (Middle Pleistocene). Wadia (1941, 1951) assigned pre-glacial (Pliocene) age to the basal part of the Lower Karewa and equated them with the Dhok Pathan of Siwaliks. Roy (1974, 1980), on the basis of diatom zonation, opined that the base of the Lower Karewa is as old as Miocene. Singh (1977) employing ostracode analysis, supported Roy's view. Bhatt (1982), while evaluating the existing data, proposed that the base of Hirpur Formation is Pontian (Pliocene) and the top goes up to the beginning of Holocene. Gupta *et al.* (1984a,b), on the basis of palynostratigraphy have suggested pre-Quaternary age to the basal part of Zone III which was later referred to as lower part aof Methawoin Member (Bhatt, 1979, 1982). The pollen yield of zone III or Methawoin Member characterizes the pre-glacial milieu. Likewise, the composition of mammalian assemblage also suggests Lower Pleistocene age for the Methawoin Member (Bhatt, 1982).

Palaeomagnetic and fission-track analyses dates the volcanic ash layer in Romushi Valley as 2.40 ± 0.3 Ma (Burbank & Johnson, 1982, 1983). These findings were later endorsed by Kusumgar *et al.* (1985). This ash layer occurs beneath the conglomerate bed of Rembiara Member at Abhom in Romushi Valley (Text-figure 2). The Olduvai event is



Text-figure 2—Lithocolumn of Hirpur Formation at Hirpur Village Upper Rembiara Valley (after Bhatt, 1989).



Text-figure 3—Karewa lithostratigraphy, correlation and geomagnetic polarity (after Agarwal *et al.*, 1989).

recorded in 50 m sequence which underlies the conglomerate bed of Methawoin Member in the Romushi Valley section (Burbank & Johnson, 1982). The top of the Olduvai normal palaeomagnetic event in the Matuyama reversed epoch is considered to mark the base of the Pleistocene and therefore, Plio/Pleistocene boundary could be drawn in the middle of Methawoin Member sequence in the Romushi Valley. Palynology too, supports the demarcation of Plio/Pleistocene boundary at the said level of Methawoin Member. The Matuyama/Brunhes contact is considered to mark lower/middle Pleistocene boundary (Text-figure 3).

PALAEOBOTANY OF KAREWAS

The occurrence of mega-plant remains was first observed by Godwin-Austen (1864) from Hirpur Formation. Thereafter, Middlemiss (1911) collected a number of fossil leaves, fruits, etc. from Liddarmarg which were later identified as *Quercus glauca, Buxus semipervirens, Alnus* sp., *Cinnamomum* sp. and *Jasminum* sp. The assemblage typifies the subtropical forest which presently grows at the height of 1,165-1,670 m a.s.l.

It would not be worthwhile to enumerate here all those references that are available on the subject but the mention of G.S. Puri's work is quite important since he has made a systematic attempt to highlight the palaeobotanical evidences burried in the Karewas and also reviewed the mega-plant remains discovered by earlier explorers. Puri (1948) re-examined several hundred plant species collected and identified by earlier workers from Karewa beds and summarized his decade's palaeobotanical observations. Almost all the plant-bearing material was procured from the strata of Hirpur Formation. The fossiliferous beds at various localities have been categorised under two main groups. The first group includes beds exposed at Laredura, Dangarpur. Butapathri, Nagbal, Gojipathri and Liddarmarg. Sediments at these places are largely composed of grey clays with blackish tinge and are compactly set into thick layers. The second group is composed of slightly coarse-grained clays often in pale yellow and occasionally bluish grey colour. These clays are thinly layered alternating with coarse and fine sediments and are known as "varves". Such beds are exposed at several places in the upper Ningle Valley and Hajabal. They are highly friable and do not prove useful for collection of fossils.

The Lower Karewa deposits towards Pir Panjal have yielded rich plant megafossils both quantity and quality-wise (Table 1). Three distinct floristic assemblages have been identified, which are termed as Laredura, Ningle Nullah and Liddarmarg floras (Puri, 1948).

Laredura flora—Laredura (lat. 34°7', long. 74°21') lies at an elevation of 2,000 m a.s.l. about 12 km south-west of Baramula town. Other equivalent fossiliferous sites clubbed in this category are Nichahom and Nagbal. Laredura flora comprises a rich plant assemblage comprising both warm-temperate and subtropical forms. It is chiefly dominated by a large number of leaves belonging to *Quercus dilatata, Q. incana, Ulmus, Alnus, Cedrus, Pinus roxburghii, Aesculus indica, Acer caesium*, etc. At present their modern representatives do not exist in the valley, rather they are confined to the lower elevations between 1,165-2,000 m a.s.l.

Ningle Nullah flora—Ningle Nullah (lat. 34°4'; long. 74°19') lies at an elevation of 3,200 m a.s.l. and could be easily approached from Gulmarg. Other equivalent sites grouped in this category are Butapathri and Gojipathri and both lie almost at the same elevation. Ningle Nullah flora is composed of exclusively temperate forms like willows, poplars, cherries, walnuts, maples, elms, alders, spruce, silver fir, blue pine, deodar, etc. Besides, well-preserved leaf fragments of *Nelumbo nucifera* have been recovered. The modern representatives of the past analogues still exist on the northern slope of Pir Panjal in Kashmir Valley occupying an elevation between 2,300-3,300 m a.s.l.

Liddarmarg flora—Liddarmarg (lat. 33°48'; long. 74°39') lies at an elevation of 3,500 m a.s.l. The clay here is blackish grey and well bedded; the nature and texture of sediments are the same as found in Laredura and Ningle Nullah localities but the flora greatly differs.

It is composed of mostly subtropical taxa but a few belong to the tropical zone as well. The important taxa encountered are *Quercus incana, Machilus* sp., *Acer oblongum, Pittosporum eriocarpum, Berchemia* sp., *Mallotus* sp., *Leea* sp., *Myrsine* sp. and *Ficus cunia*. This kind of flora does not grow in the valley rather it is confined to sub-Himalayan rain forest.

PALYNOLOGY OF KAREWAS

Kashmir Valley exhibits a complete sequence of Pleistocene and Holocene deposits in Karewas and lakes/swamps respectively which provide an opportunity to reconstruct palaeofloristics through palynology. During early days emphasis was given mainly to enumerate the taxa from sediments. Wodehouse (1935) pollen analysed samples from lower as well as Upper Karewas and quantified arboreal and nonarboreal taxa separately. Based on

Table 1—Plant fossils from Karewa, Kashmir

TAXA	PLANT REMAIN	CLIMATIC SIGNAL
LAREDURA FLORA		
Euphorbiaceae		
Mallotus philippensis	Leaf	Subtropical
Hippocastanaceae		
Aesculus indica	Leaf	Temperate
Myrsinaceae		
Myrsine sp.	—	Subtropical
Oleaceae		
Olea grandulifera	Leaf	Subtropical
Fraxinus sp.	Fruit	Warm temperate
Ulmaceae		
Ulmus wallichiana	Leaf	Warm temperate
U. laevigata	Leaf	Cool temperate
U. campestris	Leaf	
Juglandaceae		
Engelhardtia colebrookiana	Leaf	Subtropical
Lythraceae		
Woodfordia fruticosa	Leaf	Subtropical
Salicaceae		
Salix elegans	Leaf	Temperate
Fagaceae		
Quercus semecarpifolia	Leaf	Cool temperate
Q. dilatata	Leaf	Subtropical
Q. ilex	Leaf	Subtropical
Betulaceae		
Betula utilis	Leaf	Cold temperate
B. alnoides	Leaf	Cool temperate
Alnus nitida	leaf	Subtropical
Corylaceae		
Corylus ferox	—	Warm temperate
Aceraceae		
Acer villosum	Leaf and fruit	Temperate
A. caesium	Leaf and fruit	Temperate
Berberidaceae		
Berberis lycium	Leaf	Subtropical
Aralliaceae		
Hedera nepalensis	Leaf	Temperate
Papilionaceae		
Desmodium natans	Leaf	Subtropical
D. latifolium	Leaf	Subtropical
D. tiliaefolium	Leaf	Subtropical
Indigofera hepeptelea	Leaf	Subtropical
Anacardiaceae		
Rhus punjabensis		
R. succedenea	Leaf	Subtropical
Lannea coromandelica (*Odina woodier*)	Leaf	temperate
Rosaceae		
Prunus cerasiodes	Leaf	
Pyrus pashia	Leaf	

Contd.

Table 1—Contd.

TAXA	PLANT REMAIN	CLIMATIC SIGNAL
Rosa webbiana	Leaf	Subtropical-temperate
R. macrophylla	Leaf	Subtropical- Temperate
	Leaf	Temperate
Spiraea sp.	Leaf	Temperate
Cotoneaster bacillaris	Leaf	Temperate
Rubus fruticorus		
Ranunculaceae		
Ranunculus sp.	Fruit	Temperate
Clematis sp.	Fruit	Temperate
NINGLE NULLAH FLORA		
Hippocastanaceae		
Aesculus indica	Leaf	Cool temperate
Ulmaceae		
Ulmus laevigata	leaf	Warm temperate-cool temperate
Salicaceae		
Salix wallichiana	Leaf	Warm temperate-cold temperate
S. elegans	leaf	Warm Temperate
Populus ciliata	Leaf	Warm temperate
P. balsamifera	Leaf	Warm temperate
Betulaceae		
Betula utilis	Leaf	Cold temperate-subalpine
Alnus nepalensis	Leaf	Warm temperate-cold temperate
Aceraceae		
Acer pictum	Leaf	Cold temperate
A. pentapomicum	Leaf	Cool temperate
A. villosum	Leaf	Cool temperate
Cornaceae		
Cornus macrophylla	Leaf	Warm temperate
Marlea begoniaefolia	Leaf	Cold temperate
Oleaceae		
Fraxinus excelsior	Leaf	Warm temperate-cool temperate
Rosaceae		
Prunus cornuta	Leaf	Warm temperate
Pyrus malus	Leaf	Cool temperate
Cotoneaster nummularia	Leaf	Warm temperate
C. microphylla	Leaf	Cold temperate
LIDDARMARG FLORA		
Fagaceae		
Quercus incana	Leaf	Subtropical
Q. glauca	Leaf	Warm temperate
Urticaceae		
Ficus cunia	Leaf	Tropical
Euphorbiaceae		
Mallotus philippensis	Leaf	Tropical
Lauraceae		
Litsea lanuginosa	Leaf	Subtropical
Cinnamomum tamala	Leaf	Subtropical
Machilus odoratissima	Leaf	Subtropical
M. duthie	Leaf	Subtropical
Phoebe lanceolata	Leaf	Subtropical

Contd

Table 1—Contd.

TAXA	PLANT REMAIN	CLIMATIC SIGNAL
Buxaceae		
Buxus wallichiana	Leaf	Subtropical-warm temperate
B. papillosa	Leaf	Subtropical-warm temperate
Rutaceae		
Skimmia laureola	—	Tropical-subtropical
Toddalia sp.	—	Tropical-subtropical
Rhamnaceae		
Rhamnus virgatus	—	Tropical
R. triquetra	—	Tropical
Berchemia floribunda	—	Tropical
Myrsinaceae		
Myrsine africana	—	Tropical-subtropical
M. semiserrata	—	Tropical-subtropical
Rubiaceae		
Wendlandia exserta	Leaf	Tropical
Rosaceae		
Pyrus communis	Leaf	Subtropical-temperate
Cotoneaster bacillaris	Leaf	Subtropical-temperate
Spiraea sp.	Leaf	Subtropical-temperate
Berberidaceae		
Berberis lycium	Leaf	Subtropical
Cornaceae		
Dendrobenthamia capitata	—	Subtropical
Papilionaceae		
Desmodium podocarpum	Leaf	Subtropical
D. laxiflorum	Leaf	Subtropical
Asteraceae		
Inula cappa	—	Tropical
Araceae		
Acorus sp.	—	Tropical
Cyperaceae		
Scripus sp.	—	Tropical
Cyperus sp.	—	Tropical

frequency comparison of pollen in lower and upper Karewas he concluded that pollen content was essentially the same in both except for more grass pollen in the former which were almost absent in the latter. Cogner (*in* de Terra & Paterson, 1939), Iyenger and Subramanyam (1943), and Rao and Awasthi (1962) have enumerated diatom taxa from the Lower Karewa sediments, which mostly belong to Pennales. Goswami (1955-56) analysed Nichahom lignite samples and reported the occurrence of gymnospermous cuticles, a few disaccate pollen and one fern sporangium. Purekar (1962) made a report of some fungal conidia-like structures from Ningle Nullah sediments.

Nair (1960) pollen analysed some grab samples from both lower and upper Karewas. Besides, enumerating a number of arboreal and nonarboreal pollen taxa, he reflected on palaeobiogeography and migration of plants. He also observed that certain taxa like *Alnus, Carpinus, Pinus roxburghii* and *Quercus*, though present in the sediments, are absent today in the Kashmir Valley proper. Nevertheless, their counterparts do grow at present on southern slope of Pir Panjal mountains. Nair (1968) re-evaluated his previous work and provided a short pollen diagram to highlight the evolution of flora in the Lower Karewa. The approach was undoubtedly good but was sketchy and did not apply to Karewas in a larger perspective. Vishnu-Mittre *et al.* (1962), in their brief study of grab samples from the Lower Karewa dealt with floral assemblages but the data was too little to reconstruct palaeofloristics.

Vishnu-Mittre (1964) tried to apply palynology to define Plio/Pleistocene boundary but mostly without the support of palynodata. He had also not considered the demarcation of lower/middle/upper Pleistocene boundaries, rather endorsed de Terra and Paterson's (1939) view based on lithostratigraphy, that P/P boundary be drawn at the base of lithozone-I. In 1973, Vishnu-Mittre studied palynology from the four out of five lithozones, formulated by de Terra and Paterson (1939) in Lower Karewa. Vishnu-Mittre and Robert (1973) pollen analysed Lower Karewa samples and made comparative study of both micro- and megafossils from the same locality, but the results were not complementary. Later, based on diatom analysis the base of Lower Karewa was assigned Miocene age, being preponderant in centrale diatoms (Roy, 1974). However, the diatom analysis of Hirpur Loc. III sediments has revealed the preponderance of pennate diatom (Gupta & Khandelwal, 1987).

Keeping in view the high potential of palynostratigraphy and pollen yield of Karewa deposits, it was deemed necessary to investigate samples from measured sections. Several hundred samples from Dubjan, Rembiara and Methawoin members within Hirpur Formation were collected and pollen analysed. The samples were collected from all lithofacies but all of them did not yield. Lignitic muds and lignites yielded invariably a high biomass. Laminated muds at Dubjan and sands at Hirpur also yielded biota, though not qualitatively rich.

Palynological results obtained from different chronological sequence are primarily presented here separately and independently which would be later synthesized and put in unilinear manner so as to focus all vegetational shifts and their impacts on the palaeoenvironment. All possible efforts have been made to synchronize palynological findings with the up-to-date Karewa lithostratigraphy (Bhatt, 1989) and Karewa chronostratigraphy (Agarwal *et al.*, 1989).

Dubjan Member—It consitutes the oldest sequence in the Hirpur Formation and overlies the Panjal Trap basement. It consists of sand, sandy clay, clay, laminated mud, lignitic mud, etc. with sporadic pebble layers of restricted lateral extent. It has about 250 m thick section exposed and a major part is concealed below the rock debris (Bhatt, 1989). This zone was earlier referred to as zone I (Bhatt 1979, 1982). Its age has been extrapolated between 4 to 3.8 Ma and considered as Remzone I (Agarwal *et al.*, 1989). In view of the fact that only one datable volcanic ash deposit in the Karewas has been found and palaeomagnetic dating alone is not enough to provide high resolution, Agarwal *et al.* (1989) have advocated that the age estimation and extrapolation of various undated sequences in the valley could be done on the basis of sedimentation rate. As boulder conglomerates/sandstones are the result of rapid deposition and clays alone represent slow slack water deposition, they have used the thickness of mudstones to calibrate the sedimentation rate.

The total estimated thickness of the sampled Dubjan sediments for palynological investigation is around 20-23 meter. The stratigraphy is marked by lower and upper thick deposits of loose, coarse sand sandwitching several bands of lignitic mud and laminated mud alternating with each other. Pollen analytical investigations were performed on all types of lithofacies. It was found that laminated and lignitic mud are productive while sand, being coarse and porous, is almost always devoid of any biomass. The investigations have further revealed that the coherence exists in the palynological set-up throughout the pollen diagram but for the different values of different taxa. In order to elaborate significant epoch and events in time and space, the whole Dubjan diagram has been phased into three zones namely DB-1, DB-2 and DB-3 in ascending chronological order (Sharma *et al.*, 1984).

DB-1 symbolises the oak-chirpine composition but owing to constant competition amongst the forest constituents, chirpine improved and spread but oaks reduced and disappeared. Spruce was present in low values. The occurrence of deodar and birch was sporadic whereas alder was found to be fluctuatingly low. *Acacia* and *Berberis* made their way in lower and upper parts of the zone respectively. Nonarboreals are high in frequency as compared to arboreals. Poaceae made a humble beginning but improved its position in the younger strata while Cyperaceae showed contrary results. Chenopods and *Polygonum* remained sporadic throughout. Aquatic taxa, although feeble, were represented by *Potamogeton, Typha* and *Myriophyllum.*

DB-2 is featured by an erratic trend in the vegetation development and therefore to obtain precision, the zone is further divided into DB-2a and DB-2b subzones respectively.

DB-2a witnessed constant competition between chirpine and oak-woods owing to fluctuations in precipitation. Chirpine, after experiencing a serious set-back in the middle, rose to attain 60 per cent at the close of this subzone and oaks attained fairly high values in the middle but otherwise remained insignificant at the lower and upper limits of the subzone. *Alnus* continues to be abundant even at the chirpine fall but *Juglans* did not react sharply to the erratic climate, rather it maintained constant values throughout not exceeding 10 per cent. Another

Table 2—Indicates vegetational and climatic development in Kashmir Valley

STRATIGRAPHY 1	PERIOD 2	LITHOZONE 3	LOCALITY 4	POLLEN ZONE 5	CLIMATE 6	AGE 7
(Bhatt, 1989)		(Agarwal *et al.*, 1989)		(Dodia, 1988; Dodia *et al.*, 1982, 1984; Gupta & Khandelwal, 1987; Gupta & Sharma, 1989, 1992; Gupta *et al.*, 1984a, b, 1990; Sharma & Gupta, 1984; Sharma & Vishnu-Mittre, 1969; Sharma *et al.*, 1984 Singh, 1964; Vishnu-Mittre & Sharma, 1966)		(Burbank & Johnson, 1982; Kusumgar *et al.*, 1985)
	Postglacial to Deglacial		Toshmaidan, Higam, Hokarsar	Pine-Quercetum mixtum	Period of decreasing warmth.	500 years B.P.
			Butapathri Anchar	Quercetum mixtum-Pine	Period of warmth maximum	10,000 years N.P.
				Pine-Quercetum mixtum	Period of increasing warmth	14,000 years B.P.
Nagum Formation	Upper Pleistocene	Remzone, 9	Loess capping Karewas all over	Barren	Gap	0.2 Ma 20,000 years B.P.
		Remzone, 7-8		Barren	Gap	0.3-0.2 Ma
			Baltal	B-2-Blue pine-Spruce-Silver-fir	Subalpine & moist	
				B-1-Spruce-Silver fir-Blue pine	Subalpine & dry	
			Sarnar	Blue pine-Quercetum mixtum	Cool temperate & moist	0.6-0.3 Ma
	Upper-Middle Pleistocene		Wapjan	Poaceae-Chenopodiaceae-Rosaceae (*Dryas*)—*Artemisia*—Asteraceae-Apiaceae (Scrub-heathland vegetation).	Alpine desert/ Glacial milieu	0.72-0.6 Ma 2.2-0.72 Ma
			GAP			
HIRPUR FORMATION Methawoin Member (400 m)	Middle-Pleistocene	Remzone, 6	Krachipathra	BZ-Barren zone		
				KP-4-Spruce-Blue pine-Larch-Birch-Oak	Cool temperate with moderate humidity	
				KP-3-Silver fir-Spruce-Cypresses-Deodar-Blue pine	Cold temperate with moderate humidity	
				BZ-Barren zone		
				KP-2-Spruce-Cypresses-Silver fir-Blue pine-Birch-Oak	Cool temperate & humid	
				BZ-Barren zone		
				KP-1-Oak-Blue pine-Spruce-Birch-Silver fir-Cypresses	Temperate & humid	2.4-2.2 Ma
	Lower-Pleistocene					
	Upper Pliocene	Remzones-4, 5	Hirpur Loc-IV	Barren zone		2.6-2.4 Ma
		Remzone, 3	Hirpur Loc. III	H-III 15-Blue pine-Silver fir-Spruce-Birch-Hazel-Alder-Walnut	Cool temperate & dry	
				BZ-Barren zone		
				H-III 14-Oak-Poaceae	Cool temperate & moderately dry	

Contd.

Table 2—Contd.

STRATIGRAPHY 1	PERIOD 2	LITHOZONE 3	LOCALITY 4	POLLEN ZONE 5	CLIMATE 6	AGE 7
HIRPUR FORMATION (contd.) Methawoin Member (contd.)	Pontian (Pliocenė)			BZ-Barren zone		
				H-III-13-Alder-Oak-Ash-Poplar-Silver fir	Cool temperate & humid	
				BZ-Barren zone		
				H-III-12-Poaceae-Liliaceae *Potamogeton*-Cyperaceae-Ferns	Temperate & wet	
				BZ-Barren zone		
				H-III-11-Poaceae-Oak-Alder-Cyperaceae-Chenopodiaceae-*Typha*	Warm temperate & humid.	
				BZ-Barren zone		
				BZ-Barren zone		3.7-2.6 Ma
				H-III-10-Pure Chir pine forest with an admixture of Poaceae and Oleaceae	Subtropical warm	
				BZ-Barren zone		
				H-III-9-c-Pure Chir pine forest	Subtropical warm and dry	
				H-III-9-b-Blue pine-Silver fir-Spruce-Deodar-Birch	Temperate & dry.	
				H-III-9-a-Pure Chir pine forest	Subtropical warm & dry	
				BZ-Barren zone		
				H-III-8-Oak-Cypresses-Juniper-Poplar-Ash-Poaceae-*Potamogeton*-Typha	Warm temperate & wet	
				BZ-Barren zone		
				BZ-Barren zone		
				H-III-7-Pure-Chirpine forest	Subtropical warm & dry	
				H-III-6-Deodar-Silver fir-Alder	Temperate & warm	
				H-III-5-Pure Chir pine forest	Subtropical warm & dry	
				BZ-Barren zone		
				H-III-4-Larch-Oak-Poaceae-*Potamogeton*-Ferns	Warm temperate & wet	
				BZ-Barren zone		
				H-III-3-Pure Chir pine forest	Subtropical warm & dry	
				BZ-Barren zone		
				H-III-2-Larch-Oak-Carya-Walnut-*Engelhardtia*-Ash-Poaceae	Warm temperate & wet	
				H-III-1-Pure Chir pine forest	Subtropical warm & dry	
			Ningle Nullah	NN-Spruce-Juniper forest with sprinkling of *Cupressus*, Larch, Hazel and Oak	Cold temperate & & very humid	
			Hirpur Loc. I	H-I-4-Spruce forest	Cool temperate & dry	
				H-I-3-Larch-Oak-Silver fir Birch-Hazel-Alder	Cold temperate & wet	
				H-I-2-Spruce-Oak-Birch	Cool temperate & humid	
				H-I-1-Oak-Spruce-Alder-*Salix*-Ericaceae-Rosaceae	Warm temperate & humid	

Contd.

Table 2—Contd.

STRATIGRAPHY 1	PERIOD 2	LITHOZONE 3	LOCALITY 4	POLLEN ZONE 5	CLIMATE 6	AGE 7
Rembiara Member (200 m)		Remzone, 2		BARREN		3.8-3.7 Ma
Dubjan Member (300 m)		Remzone, 1	Dubjan	DB-3-Spruce-Cypresses-yew-Larch-Silver fir-*Nymphaea* *Potamogeton*-Fern	Cool temperate & wet	
				DB-2-b-Alder-Birch-Oak-Walnut-Spruce	Warm temperate & moderately humid	
				DB-2-a-Chir pine-Alder Oak-Walnut-Spruce	Subtropical/ temperate transition & moderately humid	
				DB-1-Oak-Alder-Spruce-Poaceae-Cyperaceae	Warm temperate & moderately humid	4.0-3.8 Ma

feature recorded here is the occurrence of *Picea* and *Quercus* in reasonably high values in the lower and middle of this subzone respectively. *Betula* and *Corylus* present in low values, are the two main components of *Picea*. The strength of nonarboreals as such remained poor since Poaceae reduced drastically. Marshy and aquatic taxa are scantily present.

DB-2b is characterized by low but static values of chirpine. *Betula* recorded sudden spurt in its values. Oaks, though in low values, remain constant throughout. *Corylus* and *Juglans* gained values in the beginning but declined upward. *Viburnum* is locally high. Ground cover continued to be depressed with further supression in Poaceae but *Polygonum* thrived well in the heathland. *Potamogeton* remained low but ferns were sporadically high.

DB-3 witnessed a shift in vegetation from chirpine to spruce forest. The associates of spruce like *Cupressus, Taxus, Larix* and *Abies* appeared in this zone which were otherwise absent till zone DB-2. *Quercus, Ulmus, Corylus, Alnus* and *Juglans* continued sporadically. Shrubby vegetation, in general, improved and is marked by high values of *Fraxinus* and low values of *Viburnum* and Poaceae. Shrubby taxa go very well with the spruce forest as the exterior components of the forest denote cold climate. Sudden spurt in Poaceae and its consistency throughout is another notable feature of this zone. Other herbs such as Chenopodiaceae, Urticaceae, Liliaceae, Asteraceae, Cyperaceae and *Polygonum* improved. *Nymphaea* and *Potamogeton* improved but *Typha* remained in low profile. Ferns improved to the maximum indicating congenial conditions for their revival and survival.

Rembiara Member—de Terra and Paterson (1939) described it as 'basal gravel fan' and considered it to be the base of Lower Karewa. Farooqi and Desai (1974) termed it as 'Hirpur conglomerate' and inferred that it was not developed elsewhere in the basin except for the upper Rembiara Valley section. Bhatt (1989) thoroughly studied the basin development and found 'conglomerate horizon' or 'Rembiara Member' is a regular lithological unit of Hirpur Formation and is developed in all the sections. It has earlier been referred to as Zone-II. The thickness of the Rembiara Member in the type section is from 200-225 m (Bhatt & Chatterji, 1976; Farooqi & Desai, 1974). It consists mainly of conglomerate deposits with occasionally and irregularly developed sand and clay lenses. It is considered to be a rapid deposition zone as a result of a major uplift of the Pir Panjal.

A large number of samples from both sand and clay lenses were tried for palynological investigations but they were almost always found palynologically barren and hence no sustainable vegetational and/or climatic picture could be established.

Methawoin Member—It is named after a small *marg* up the cliff opposite to Hirpur Village, making the youngest lithological unit of the Hirpur Formation (Bhatt, 1989). It was earlier referred to as Zone-III (Bhatt, 1979, 1982). It consists of a succession of sand, sandy clay, clay, lignitic mud, laminated mud and lignitic bands. However, its lignitic bands are thinner as compared to Dubjan. The total thickness of the Methawoin Member in the type section is between 350-400 m. Chronologically, it has been put under Remzone III and covers a time span between 2.92 to 2.6 Ma.

About 200 m thick sediments covering all lithofacies were sampled for palynological investigation. The most important aspect in this sequence is that besides lignitic mud, laminated mud, and lignite, some sand samples have also yielded enormous quantity of pollen. The palynological investigations of Methawoin Member have been carried out in the name and style of Hirpur Locality-I, III and IV (Gupta & Sharma, 1989; Gupta *et al.*, 1984a, b). Hirpur Locality I and III have yielded rich pollen assemblages both quantitatively and qualitatively but Hirpur Locality IV did not yield sufficient pollen for percentage calculation. The variation in the output of pollen is largely due to the porosity of Hirpur Locality IV sediments which might have led to oxidation and destruction of pollen and spores.

Hirpur Locality I—Sediments of Hirpur Locality I constitute the basal part of the Methawoin Member and consist of laminated and lignitic mud with distinct overlying and underlying beds of sand making a total thickness of 40 m. A large number of samples were pollen analysed. Only lignitic mud yielded pollen in appreciable frequency, whereas other lithofacies proved to be palynologically barren.

The overall vegetational picture indicates the predominance of *Picea* and *Quercus* together with other broad-leaved arboreals. On the basis of subtle vegetational shifts, it has been possible to phase the whole pollen diagram into four assemblage zones, viz., HLI-1 to HLI-IV in ascending chronological order.

HLI-1—The early phase of this zone is recognized by exceedingly high values of *Quercus* followed by *Picea, Alnus, Salix, Acacia*, Ericaceae and low values of *Abies*. Nonarboreals are scantily present. AP/NAP ratio has demonstrated the predominance of arborescent vegetation. The later phase of this zone is marked by a steep fall in the values of *Quercus* and *Picea*. *Carpinus* and *Berberis* appeared, whereas *Salix* and Ericaceae disappeared in this phase. *Alnus* remained static. *Arcicolpites hirpurensis* (Gupta *et al.*, 1990) and Rosaceae appeared in this phase and maintained 17 per cent each. Poaceae improved and attained maximum values of 20 per cent, whereas other herbs remained low. AP/NAP ratio shows considerable decline in the arboreal vegetation as compared to early phase of this zone.

HLI-II—This zone is identified by the preponderance of *Picea* pollen throughout indicating a shift of vegetation from preceding zone and establishment of spruce forest. *Quercus* declined to moderate values and remained confined to the middle of the zone. Spruce associates namely *Juniperus, Larix, Betula, Carpinus, Ulmus*, etc. are sporadic. *Alnus* continued in moderately high values till the beginning, declined in the middle and disappeared in the upper half of this zone. *Carya* appeared in moderately high values right in the beginning and continued throughout with enhanced values upward. *Juglans* appeared in the lower half and continued throughout in fairly high frequencies. Shrubby taxa like Berberidaceae and Rosaceae are present in low and high values respectively almost throughout but both vanished at the close of this zone. *Arcicolpites hirpurensis* is present throughout in quite high frequencies but relatively lesser than the preceding zone.

Nonarboreals have distinctly low values in this zone. Poaceae, having exceedingly high values in the later phase of preceding zone, was reduced to a fraction in the beginning of this zone. However, Poaceae gradually improved and continued to gain high values till the end of the zone. *Typha* and *Potamogeton* are present in relatively improved values than before. AP/NAP ratio portrays the overall dominance of arborescent vegetation.

Zone HLI-III—It is markedly a short phase which experienced an abrupt fall in spruce forest to the tune that it shrunk to a fraction. The downfall of spruce is witnessed by corresponding rise of *Larix* and *Quercus* in almost equally high values and this followed by *Abies, Betula, Carpinus, Alnus* and *Juglans*. *Carya* disappeared but *Engelhardtia* emerged in this zone. *Arcicolpites hirpurensis* is surprisingly absent in this zone. Ground cover seems to have further reduced. Aquatic taxa and fern spores are absent. AP/NAP ratio continues to maintain predominance of arborescent vegetation.

Zone HLI-IV—This zone is represented by the re-emergence of spruce forest in exceptionally high values (80%). *Juglans* improved but *Betula, Alnus* and *Salix* reduced. No shrubby element is recorded in spruce wood zone. Ground vegetation is represented by scanty values of Poaceae and Primulaceae only. Aquatic taxa are almost absent except for low values of *Typha*. AP/NAP ratio depicts the sketchy presence of nonarboreals in contrast to the arboreals.

Hirpur Locality III—It constitutes the major lower-middle part of the Methawoin Member comprising almost the same lithofacies as found in Hirpur Locality-I. The only difference between the two is that even sand samples have yielded pollen which were otherwise absent in Hirpur Locality I.

Pollen investigation of about 200 m thick (vertical cliff) strata has been carried out.

Palynological investigations of Hirpur Locality-III sediments (Gupta *et al.*, 1984a, b) have suggested unstability, cyclicity and reversibility in vegetation owing to changing climatic conditions. On the basis of these observations the pollen diagram drawn from Hirpur Locality-III has been classified into fifteen pollen zones and thirteen barren zones reflecting on periodical shifts in the vegetation and covering a time span of around half a million years. These zones are initiated from HL-III-1 to HL-III-15 in ascending chronological sequence. Henceforth, for all practical purposes, I prefer to use zones 1-15.

Zone-1 is populated by 79 per cent of chirpine of the total population. A subtropical and dry climate is inferred. It characterizes the pure chirpine forest with a little underground herbaceous vegetation composed of Poaceae, Chenopodiaceae, etc. Zone 2 represents notable change-over from pure chirpine woods to mixed conifer quercetum-mixtum forest, indicating a broad climatic catastrophe. *Carya, Fraxinus, Larix*, etc. are other important taxa of this mixed community. *Arcicolpites hirpurensis* appears in low values after its disappearance from the upper phase of Hirpur Locality I. Amongst nonarboreals, Poaceae dominated and other herbs trailed. High values of aquatic taxa like *Nymphaea, Myriophyllum* and *Potamogeton* were recorded.

Zone-3 is marked by reversibility of the type of vegetation of Zone-1 wherein chirpine formed the pure forest with little understorey of a few tree stands and little ground cover of grasses and other herbs.

In Zone-4 no chirpine pollen has been noticed. They have been replaced by the high values of *Larix* (23%), *Quercus* (10%), *Engelhardtia* (6%) and *Alnus* (2%). Non-arboreals are largely dominated by grasses alongwith some chenopods. *Potamogeton* and ferns became abundant while *Typha* reduced to low values.

Zone-5 again records the pure chirpine forest touching the peak of 81 per cent of the total vegetation, wherein *Alnus* and *Salix* have 4 per cent representation. The rest is represented by grasses. Climate remained subtropical and very dry.

Zone-6 has witnessed a slight deviation from the routine picture of vegetational development. It records deodar forest wherein silver fir and alders also make their way in low proportion with sprinkling of poplar, walnut, Fabaceae and Oleaceae. Poaceae, *Artemisia* and ferns compose the ground vegetation in low profile. Aquatic taxa record high values for *Pediastrum* and low values for *Potamogeton* and *Nymphaea*.

Zone 7 is another phase wherein the reversibility and cyclicity of vegetation could be observed. It is marked by excessively high values of chirpine, attaining a new height of 94 per cent of the total population. In this pure chirpine woods, the stray occurrence of *Juglans, Salix, Artemisia*, Chenopodiaceae and Poaceae is noticeable. Water plants completely absent. Such a vegetation seems to have developed under subtropical and dry climate.

Zone-8 depicts entirely different type of vegetation composition wherein the open conditions spread far and wide ceding pace for better development of nonarboreals. Arboreal taxa encountered, varying from moderately high to low, are *Quercus, Fraxinus, Populus, Cupressus, Larix*, etc. and *Carpinus, Alnus, Salix, Engelhardtia*, etc. respectively. Water plants improved satisfactorily. Ferns and bryophytes also found conducive conditions to colonize.

Zone-9, although spanned for a short period, has recorded rapid changes in the vegetational shifts. For instance, chirpine/bluepine/chirpine phases are the major events during this period and have been marked by three subphases in the pollen diagram, viz., subzones a, b and c. Fluctuations in the climate from warm-cold-warm have led these shifts in vegetation.

Zone-10 is a transitional zone wherein the pure chirpine forest of preceding subzone-9c is on decline and ultimately replaced by vast stretches of grassland with little proportion of oaks and oleaceous shrubs invading the grassland towards the close of this zone. Water plants improved very satisfactorily and recorded *Potamogeton* (25%), *Typha* (5%) and *Polygonum* (7%). These shifts in the vegetation are indicative of dramatic change in climate from very arid to very humid recording high degree of precipitation.

Zone-11 is almost the continuance of preceding zone denoting the open grasslands wherein oaks have improved and were also joined by *Abies, Juniperus, Larix, Betula, Carpinus, Carya*, etc. indicating a slow and gradual invasion of woods into the grassland. Water plants also reduced to a fraction. There was practically no noticeable change in the climate than the preceding zone except for slight depression in precipitation.

Zone-12 is almost a tree less zone except for sporadicity of silver fir and oleaceous shrubs. There is a total coverage by the non-arboreals. However, Poaceae does not make any break-through in building the grassland instead Liliaceae, Cyperaceae and ferns made their headway in formulating the non-arboreals to dominate. *Potamogeton* and other water plants inhabit the lakes and lake margins.

Thus, the zone has witnessed torrential rains and cloud bursts inundating the land mass within temperate climatic regime.

Zone-13 is marked by entirely a different set up of vegetation composition and typifies the cool temperate climatic regime with moderate precipitation. Under this set up *Alnus, Quercus, Fraxinus, Populus* and *Abies* are dominant; *Carpinus Salix*, Rosaceae, etc. are co-dominant and Tubiliflorae, Brassicaceae, Cyperaceae, etc. are low. *Typha* is high but *Potamogeton* is moderate.

Zone-14 depicts more or less the continuance of cool temperate climatic regime although further reduction in precipitation is recorded. With this fluctuating trend in precipitation the vegetation mosaic also changed as the values of nonarboreals bye-passed arboreals. Amongst tree taxa *Quercus* is high; *Juglans, Alnus, Carpinus, Larix, Engelhardtia*, etc. are moderate and *Cedrus, Juniperus*, Rosaceae, etc. are sporadic. Aquatic and fern taxa are moderate.

Zone-15 is composed of mixed conifer-broad-leaved forest. Arboreals' spread was so high that it dominated the nonarboreals. The ratio of conifer and broad-leaved elements is almost equal in this zone except for their positions within the same altitudinal range. With this set up of vegetation, cool temperate and dry conditions are construed.

Hirpur Locality-IV—It constitutes the middle-upper part of Methawoin Member and is denoted by conglomerate bed (Bhatt, 1989). It can also be correlated with Remzone-4 (Agarwal *et al.*, 1989). This conglomerate bed is around 20 m thick. A few samples from the mud lenses proved palynologically unproductive.

Ningle Nullah—It consists of bluish-grey and violet clay, coarse to medium green sand, light-grey sandy clay and lignite. It represents the lower-middle part of the Methawoin Member but earlier it was informally thought that Ningle Nullah sediments directly overlie the Panjal Trap basement forming the base of Hirpur Formation and equated with Dubjan Member. The palynological study suggests the superimposition of Ningle Nullah sequence at the base of Hirpur Locality-III or on the top of Hirpur Locality-I.

Nine samples from different lithofacies at Ningle Nullah section, covering a vertical thickness of about 20 m, have been pollen analysed. But only four samples, two each from lignite and blackish clay yielded pollen and spores while rest of the samples from sand and mud facies turned unproductive (Gupta & Sharma, 1992). The pollen diagram has revealed uniformity in palaeovegetation and an overall dominance of arboreals over nonarboreals is recorded.

The study has brought to light the existence of *Picea-Juniperus* forest with the sporadic presence of *Cupressus, Larix, Betula, Carpinus* and *Quercus*. This type of vegetation develops under cold temperate and subalpine transition climatic regime. Further, the evidence of high precipitation and expansion of lake margins are exemplified by the abundance of marshy and water plants.

The occurrence of *Arcicolpites hirpurensis* in the lower samples has enabled the author to correlate with the basal part of Hirpur Locality-III.

Krachipathra—It constitutes the lower-upper part of the Mathawoin Member and partly covers Remzone-6. It covers a time span between 2.4 to 2.2 Ma. Out of three lithofacies recognized in 50 m Krachipathra sequence, only two—lignitic mud and laminated mud, turned to be productive both quantitatively and qualitatively. The sand samples except for the lower most of the litholog proved barren.

Palynological results from Krachipathra, though coherent in general vegetational set up, differ in the values for different taxa and therefore, the whole pollen diagram (Sharma & Gupta, 1984) has been classified into four pollen assemblage zones, viz., KP-1 to KP-4 in ascending chronological order. Likewise three barren zones have been recognized intervening pollen zones, which have not been used for any practical purpose except to show that the conditions were not conducive for the preservation of biota.

Zone KP-1 is largely composed of muddy sand and characterised by the occurrence of high values of *Quercus semecarpifolia, Pinus wallichiana, Betula, Juglans, Cupressus, Picea* and *Alnus* are present in relatively low values. The former taxa declined and vanished but latter taxa improved upward. In addition, *Abies, Cedrus* and Rosaceae made their way in good values at the close of this zone. Nonarboreals are represented mostly by grasses. Water plants and ferns on the whole, have high values. This type of vegetation thrives well under temperate and wet climatic regime.

Zone KP-2 is marked by a decline in oak-pine woods. Spruce rose tremendously at the beginning but declined upward. The decline of spruce woods corresponds to the spurt of *Abies* and *Cupressus*. *Cedrus* reappeared at the top and *Betula* remained consistently high throughout the zone. *Alnus* and *Juglans*, high in the beginning, declined upward. Herbage remained predominated by grasses. Water plants and ferns continued to be high as in the preceding zone. This shows that the climatic conditions further deteriorated.

Zone KP-3 is dotted by sudden and abrupt spurt in *Abies* in particular and conifers in general. Angiosperms, both arboreals and nonarboreals including water plants have reduced considerably as compared to the preceding zone. The climatic conditions continued to be the same except for some reduction in precipitation.

In Zone KP-4 both *Abies* and *Cupressus* suddenly declined and succeeded by *Picea, Betula, Quercus, Corylus* and *Ulmus* indicating a little amelioration in temperature.

Wapzan—It constitutes the upper most part of Methawoin Member and its age has been extrapolated between 0.7-0.6 Ma. Close to Anantipur Canal headworks, linear lenses of Lower Karewa beds are exposed, probably due to neotectonics. They are unconformably superimposed by the Upper Karewa sediments of Saki Paparian facies. The sample was collected from the lignitic lense of the Lower Karewa exposure and investigated palynologically.

Arboreal vegetation is almost negligible and is represented by bluepine-oak woods not exceeding more than 5 per cent of the total vegetation composition. Amongst nonarboreals, Poaceae and Chenopodiaceae predominate attaining 35.5 per cent and 36 per cent values respectively. Rosaceae (*Dryas*) and *Artemisia* are the codominant taxa in the assemblage. Caryophyllaceae, Asteraceae and Apiaceae are low to very low in values. Marshy and swampy taxa belonging to Ranunculaceae, Cyperaceae and *Typha* are scantily present, whereas *Potamogeton* is sporadic.

Wapzan's palaeofloristic assemblage categorically reveals the presence of meadows and/or scrubs-heathlands comparable to the modern alpine desertic vegetation of Ladakh (Dodia *et al.*, 1982). Arboreal taxa in this composition are absent. Nevertheless, certain tree taxa like *Betula, Juniperus*, etc. do extend their limit up to tree-line albeit dwarf and are stunted to the maximum of a few feet in height. However, pollen record of bluepine and oak do not go well with the composition known from Wapzan. Instead, pollen of these two tree taxa might have been blown up and mixed in the pollen rain there. Thus, the set up of vegetation composition at Wapzan enunciates the existence of glacial milieu around 0.7-0.6 Ma.

Baltal—It is exposed along the Romushi River about 60 km south-west of Srinagar. It covers 55 m thick deposits consisting mainly of bluish, compact, fractured mud and yellowish, laminated clays intercalated with fine to medium grained, greenish sand. Extrapolated date for Baltal section could be to a time bracket of 0.6 and 0.2 Ma.

The face value evaluation of the pollen diagram has revealed the overall dominance of conifer woods including bluepine, spruce and silver fir. Other arboreal taxa are either low or sporadically present in the conifer forest. Nonarboreals too, except for locally high values for Cheno/Ams, are meagerly present.

On the pattern of vegetation composition, two phases have been demarcated. Phase B-1 (between 10 to 30 m) is characterized by spruce-silver fir-bluepine forest, denoting subalpine and moderately moist climatic regime. Phase B-2 (between 31 to 47 m) has witnessed rise in the values of pine and corresponding fall in spruce and silver fir. Cheno/Ams. have suddenly spurted indicating increase in aridity under the subalpine climatic regime (Dodia, 1988).

Diatom analysis from Baltal samples has revealed the occurrence of both centric and pennate diatoms. Further, the existence of *Pinnularia, Stauroneis* and *Cymbella* have suggested subalpine climate (Gandhi & Mohan, 1983).

PALYNOLOGY OF LAKES AND SWAMPS IN KASHMIR

Palynological investigations have been carried out on several lakes and swamps representing postglacial and Holocene time span, whereas others represent a part of Holocene Period. Toshmaidan (Singh, 1964; Singh & Agrawal, 1976) and Butapathri (Dodia *et al.*, 1984) have been dated around 15,000 and 17,000 yrs B.P. respectively. Anchar and Hokarsar Lake sediments (Dodia *et al.*, 1984) have been dated *ca.* 4,000 and 1,150 yrs B.P., respectively. Haigam (Vishnu-Mittre & Sharma, 1966), Baba Rishi and Yus Maidan (Sharma & Vishnu-Mittre, 1969), Burman and Walanwar (Singh, 1964) profiles are not yet dated radiometrically. However, evidence from vegetational development indicates that the Haigam lake represents complete Holocene sequence, whereas other lakes are shallow and represent either middle or upper part of the Holocene Period.

Pollen analytical evidence from postglacial deposits suggest three-fold vegetation development, viz., pine—quercetum mixtum-pine. This pattern of vegetation development reflects on three-fold climatic oscillations, viz., cool-warm-cool coinciding with the worldwide scheme of postglacial climatic changes put forward by von Post (1946).

CONCLUSION

Kashmir Valley, as a result of combined study of litho-stratigraphy, palynostratigraphy, fission-track, palaeomagnetic and 14C dating, provides a long sequence of changing pattern of vegetation and climatic oscillations.

Vegetation composition characterizing chirpine-oak-alder-spruce-walnut-Poaceae remained almost uniform between 4.0 to 3.8 Ma except for some minor variations at the top where spruce replaced chirpine. The frequency of water plants also improved slightly. Thus, the climate seems to be warm-temperate, becoming cooler towards the top of this phase. Between 3.8 to 3.7 Ma, there is no pollen record available and hence nothing could be construed about the climate.

Cyclicity in the vegetation development had been quite evident from 3.7 to 2.6 Ma. Between 3.7 to 3.5 Ma, the vegetation was mostly dominated by spruce forest denoting cool/cold temperate type of climate. Thereafter, a catastrophy in the vegetation composition took place resulting into the establishment of subtropical and dry climate. This encouraged the colonization of pure chirpine forest. However, this type of vegetation did not last longer and the change in vegetation mosaic became inevitable owing to changing pattern in palaeoclimate. This shift in vegetation is marked by the onset of warm temperate type of climate. Thus, the climatic cycles of subtropical and warm-temperate alternating with each other could be worked out till about 2.8 Ma. Thereafter, temperate climatic regime was set-in. Slow and gradual deterioration in temperature continued till 2.6 Ma where cool temperate and dry climate developed encouraging the establishment of bluepine-silver fir-spruce forest.

Hirpur Locality-IV, covering a time span between 2.6 to 2.4 Ma proved to be palynologically barren and hence climatic inferences could not be made.

From 2.4 to 2.2 Ma, there existed typical temperate climate in the beginning which successively became cooler and ultimately cold temperate climate was established towards the top. Krachipathra sequence encompasses this time span and is marked by the establishment of silver fir-spruce-cypresses forest.

Between 0.72 to 0.6 Ma, the vegetation encountered here belongs to alpine scrubs with the preponderance of Rosaceae (*Dryas*), Chenopodiaceae, Asteraceae, Apiaceae, Poaceae, etc. This grade of vegetation forming meadows is generally found in the alpine desert areas above the tree-line zone and could be equated with the present day vegetation of Ladak where usually no arborescent plant is found. Nevertheless, certain tree taxa are found albeit in dwarf posture. Considering the type of vegetation met in Wapzan sediments, it is envisaged that glacial conditions must have prevailed during the period between 0.72 to 0.6 Ma.

Between 0.6 to 0.3 Ma, the glacial influence began to sink and late glacial conditions switched on ceding pace to establish spruce-silver fir-bluepine forest typifying the existence of subalpine climate.

Loess, capping the Karewa scarpment all through the valley, was deposited between 0.3 to 0.2 Ma. It has yielded no pollen and spore, rather it is devoid of biomass. Therefore, nothing could be committed about the prevailing climatic conditions except to say that loess is mainly of aeolian nature and indicative of enhanced aridity.

Thereafter, postglacial period began which could vary at places from 20,000 to 15,000 yrs B.P. We have plentiful records of postglacial events from lakes and swamps in the valley. With the help of 14C dating the age has roughly been estimated about 17,000 yrs B.P. at Butapathri and 15,000 yrs B.P. at Toshmaidan. The postglacial vegetation all through the valley is marked by a three-fold development, viz., pine-quercetum mixtum—pine in chronological order. This line of vegetation set up is greatly influenced by the period of increasing warmth, period of maximum warmth and period of decreasing warmth respectively or in nutshell it could be spelled out as cool-warm-cool.

To summarize, the climate does not seem to be static for a long period rather it remained changing all through the basinal development in the valley since four million years. The concept that Kashmir Valley witnessed four-fold glaciations is untenable in the light of recent multidisciplinary data. Nevertheless, palynological findings have high-lighted the monoglacial concept, contrary to lithological and sedimentological evidences (Singh, 1982; Tandon *et al.*, 1982) which does not record any glaciation in Kashmir Valley.

The discovery of *Arcicolpites hirpurensis* (Gupta *et al.*, 1990) from the Hirpur Formation has greatly helped to superimpose Ningle Nullah sequence over Hirpur Locality-I and under Hirpur Locality-III. P/P boundary is also suggested to be drawn at the top of zone-10 of Hirpur Locality-III where *Arcicolpites hirpurensis* pollen disappears and this boundary falls almost in the middle of Methawoin Member.

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