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PALAEOCLIMATIC DATA FROM KASHMIR : A SYNTHESIS AND SOME CORRELATIONS

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The Kashmir Karewas (fluvio-lacustrine sediments) have been studied under a multidisciplinary project for the last 6 years. A summary of the palaeoclimatic events derived from palynological, stable isotopic, mineral magnetic and other data is given. The time frame is provided by palaeomagnetic, fission track, TL and ^{14}C dating. The time span covered is 4Myr. The Kashmir climatic trends follow the global pattern with some regional variations.

Key Words : Palaeoclimate; Multidisciplinary Data; Kashmir; Karewas

INTRODUCTION

THE Kashmir valley is marked by flat topped plateau surfaces, called *Karewas* in the local language (now in geological literature), which are the remnants of the lacustrine sediments of the primaeval Karewa lake; the rest of the Karewas have been washed away by the Jhelum and its tributaries. The boat shaped Kashmir valley about 140×40km in extent, is essentially an intermontane valley fill basin. It is generally agreed that due to the rise of the Pir Panjal range round 4Myr, the Himalayan drainage was impounded and a lake of about 5000sq km was formed; half of these relict lacustrine sediments are still extant in the form of Karewas. Most of the geologists agree that these are lacustrine sediments.[1–3] The lake shifted towards the northern side due to the thrusting of the southern (SSW) block, as a result of which the lake sediments thus exposed provided a stable substratum for the deposition of the loess. This event took place around *c.*200 Kyr ago.[4] The Jhelum emerged at about 80Kyr and drained out the shrunken lake thus exposing further lacustrine surface for loess deposition. As a result, the northern part of the valley has only 10m of loess deposit, compared to *c.*20m in the southern part, Tandon *et al.*[5] and Singh[3] have carried out detailed sedimentological studies on the Kashmir Karewas. Lithostratigraphically, the Karewas exposed by the Rembiara river have been divided into 6 zones and those exposed by the Romushi river into 9 zones.[4] On the basis of magnetostratigraphy and fission track dates, we have ascribed them to about >3.5Myr. For the loess deposits we now have TL dates[15] as also ^{14}C dates.[14] For bogs and living lake sediments we have now a number of ^{14}C dates.[6] Thus we have a well-defined chronostratigraphy to delineate the climatic changes the valley witnessed during the last *c.*3.5Myr.

A variety of data are now available for reconstructing the palaeoclimate of Kashmir. A review of these data was published by Agrawal.[4,7–11] Since then more

palynological, mineral magnetic, geochemical, micromorphological analyses etc. have been carried out. The author presents a summary of the multidisciplinary data some of which have been presented in this volume and some published elsewhere. As the basic data have been discussed in detail elsewhere by various workers, I will confine here to the conclusions derived from the data unless the details are necessary for discussion.

Climatic Changes

Table I summarises the climatic sequence as derived from the pollen data [6,10,12] (Dodia, in press). As indicated by the Dubjan profile (Rem zone-I; 3.5Myr) the climate of Kashmir was essentially temperate with some variation in precipitation. These basal sediments are followed by a massive conglomerate (Rem zone-2) of about 200m thickness (Fig. 1). This obviously was the result of a major uplift of the Pir Panjal. From Rem zone-3, we find a subtropical type of climate dominating the valley vegetation till we reach H-12 stratum. From then onwards, progressive cooling becomes pronounced. The first cold temperate and dry phase is encountered at the top of Rem zone-3 which is roughly at the Gilbert Gauss boundary. Unfortunately, the Hirpur-IV sequence (upper part of Rem zone-4, 5; see Fig. 1) is either essentially barren or has not been studied so far.

After the gap of Rem zones 4 and part of 5, the sediments exposed at Krachipathra site on the Rembiara (Hirpur-VI) show a normal polarity, which is identified as the Olduvai event. Essentially Krachipathra sediments (KP-I to IV) represent a cool temperate climate with little variation in precipitation in each zone.[9]

It may be pointed out here that the Olduvai event is marked by the first appearance of a unique arvicolid (fossil rodents) called *Kilarcola*[11] in the Kashmir valley. The fossil arvicolids are essentially of a cold glacial period. This event in the Romushi section is also marked by the occurrence of *Cervus punjabiensis*.[7] Krishnamurthy *et al.*[13] have also reported a high C/N ratio and low $\delta^{13}C$ value at the Olduvai sub-chron. All these measurements indicate that this period represents a cold phase with low lake levels. This interpretation is based on the premise that during cold (glacial) periods, the lake levels go down because a lot of water is locked up in the form of ice sheets and the terrestrial vegetation dominates the former shorelines. On the other hand, during high lake levels of interglacial periods, the lakes enlarge and the aquatic vegetation dominates the former margins of the lake. As terrestrial vegetation has high C/N ratio and low $\delta^{13}C$, there is an anticorrelation between the two[13] (Fig. 2). We may point out here that at 2.0Myr (Reunion sub-chron) also, a cold phase is indicated by isotopic studies.[13]

At the beginning of the Brunhes chron (0.73Myr) also a cold period with low lake levels is indicated. As explained below, this cold period seems to coincide with the first cold phase of the Baltal locality as indicated by the broad leaved/conifers (B/C) ratio of about 0.01 as against B/C ratio of >0.1 during interglacial phases (Dodia, this volume).

TABLE I

Karewa Pollen Profile

Age (Myr)	Site	Pollen Zone	Climatic conditions
0.2	Romu		
		B-9	Cold and Arid
		B-8	Cool and Dry
		B-7	Cold and Arid
		B-6	Cool Temperate and Wet
	Baltal	B-5	Cold and Arid
		B-4	Cool Temperate and Wet
		B-3	Cold and Arid
		B-2	Cool Temperate and Wet
		B-1	Cold and Moderately Wet
	Srarnar		
0.7	Krachipatra	KP-4	
		KP-3	Cool Temperate with little variatiou in
		KP-2	precipitation in each zone.
		KP-1	
2.0	Hipur-IV		Barren
2.5	Hirpur-III	H-15	Cold Temperate and Dry
		H-14	Cold Temperate and Dry
		H-13	Cold Temperate and Dry
		H-12	Temperate with excessive humidity
		H-11	Progressing Cooling
		H-10	Sub-Tropical Warm
		H-9	Sub-Tropical Warm
		H-8	Warm Temperate and Wet
		H-7	Sub-Tropical and Arid
		H-6	Cold Temperate
		H-5	Sub-Tropical and Arid
		H-4	Warm Tropical and Arid
		H-3	Warm Temperate and Arid
		H-2	Warm Temperate and Arid
		H-1	Sub-Tropical and Arid
3.0			Barren
<3.15	Dubjan	DB-3	Temperate with greater precipitation.
		DB-2	Temperate with less precipitation
		DB-2B	With increasing Warmth
		DB-2A	Warm Temperate Transition

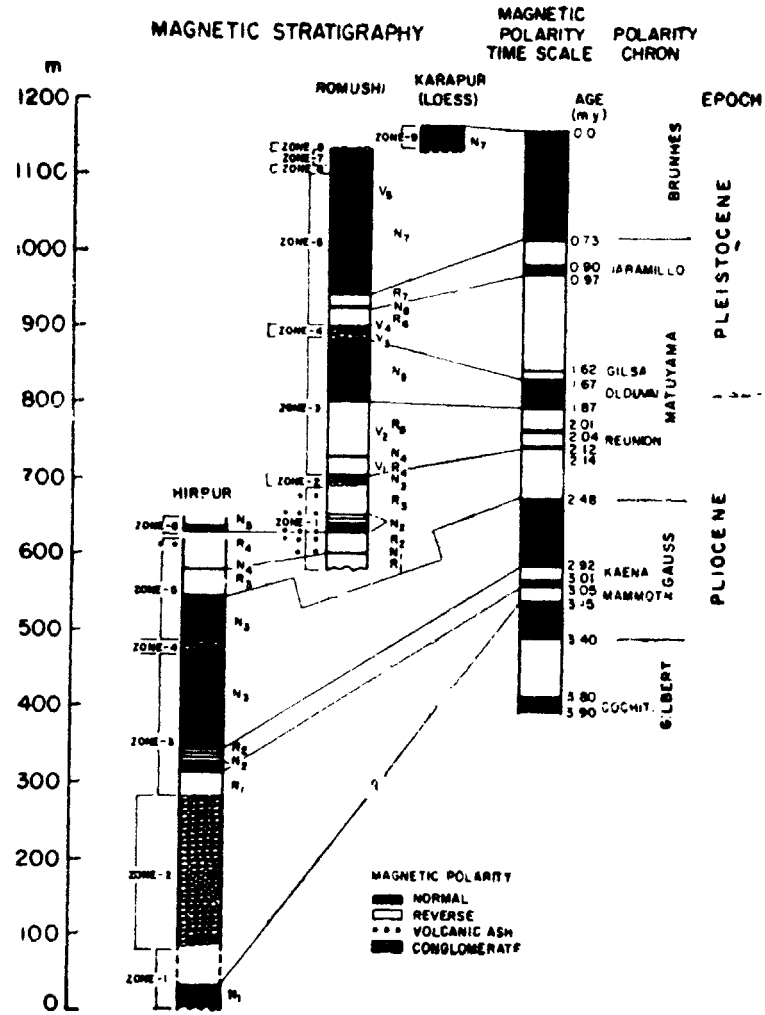

FIG 1 Magnetostratigraphy of Karewas (Kashmir). The Hirpur section (left column) shows the Rembiara lithozones (REM-1 to REM-6) and the Romushi section (middle column) shows the Romushi zones (ROM-1 to 9). The right hand column shows global magnetic stratigraphy and its correlation with REM zones 1–6 and ROM zones 1–9.

This brings us back to the Karewa section as represented by the Srarnar and Baltal localities exposed by the Romushi. The Srarnar Baltal sections fall roughly at the boundary of Brunhes/Matuyama chrons. The Srarnar section represents the beginning of the Brunhes chron and shows normal polarity.

It needs to be emphasised that the major part of the Romushi section represents the total Matuyama chron and the Hirpur section covering the upper part of Gauss section and spanning the total Matuyama chron (Fig. 1) is not completely studied palynologically so far, though parts of it are barren also. We, therefore,

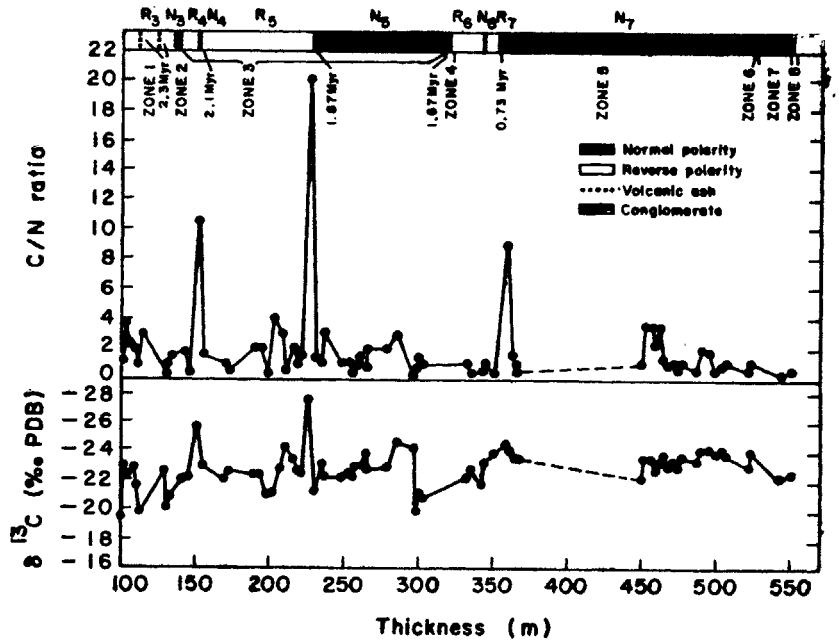

FIG 2 $\delta^{13}C$ and *C/N* ratios of lignite seams in the Karewas exposed by Romushi are plotted against the timescale provided by magnetostratigraphy. High *C/N* ratios and low $\delta^{13}C$ values coincide to mark cold conditions.[13]

still have large lacunae in the palynostratigraphy of the Karewas studied so far. The work on these gaps in the sections is still on.

With five cold periods and interglacials the Romushi section covers about 500Kyr (Dodia, in this volume). The uppermost part of the section falling within the Brunhes chron is represented by loess deposits. Before we discuss the palaeoclimatic data from the loess, we need to digress a little to discuss the palaeogeography and chronology of loess.[14]

The primaeval Karewa lake was flanked by steep ranges of the Pir Panjal and the Himalayas. And if there was any loess deposition during this time it must have been mixed up with the lake sediments. Around 200Kyr, the southern (SSW) block of the Pir Panjal got uplifted thus shifting the lake towards the northern side and putting an end to lacustrine sedimentation on the southern side. The extensive fanglomerates exposed by the Rembiara river are probably caused by these major upheavals. As a result, the southern block became available for loess deposition over the conglomerates and other deposits. These thicker (20m) loess deposits are showing about 10 palaeosols. The lake sediments on the northern side got exposed for loess deposition only around 80Kyr when the Jhelum emerged and drained the northern Karewa lake. On this side we have only 10m thick loess deposits with 5–6 palaeosols.[14]

Palaeoclimate from the Loess

As pollen has not survived in the loess deposits because of their high alkalinity and aerobic environment, we tried to use other proxy data to derive climatic inferences.

Without going into the details of the chronological controversies[12,14,15,16] we would like to emphasise here that the loess deposits in Kashmir cannot be older than 200Kyr, Bronger *et al.*[16] have suggested five interglacials in the loess profile, an interpretation challenged by Rendell *et al.*[15] based on their detailed sedimentological and micromorphological studies and TL dating. In the loess record there seems to be a periodicity of 20Kyr of climatic amelioration probably corresponding to precession of equinoxes.

There is no high resolution available in the loess profile and therefore the climatic record of the last 20Kyr is based on the pollen spectra of the bogs as discussed below.

Bog Pollen Profiles

A detailed pollen record of the Kashmir valley is still far from complete. Besides parts of the Karewa lake profile, the loess deposit covering the last 200Kyr is also sterile in pollen. The Upper Karewa lacustrine sediments which cover about 200 to 80Kyr equivalent to the lower half of the loess deposits are also very alkaline and sterile in pollen. The present day lakes, which are essentially left-overs of the primaeval lake, have been cored with Mackereth corer only recently and there is no study of the pollen record from these lake cores so far. The bogs that were drilled with hand augers provide pollen record only upto *c.*17Kyr. We summarise the bog pollen data below.

Butapathri, a site at about 3500m a.s.l., shows that the broad-leaved elements start appearing at *c.*17Kyr (Fig. 3). This is indeed close to the glacial maximum as reported from the sea cores. Soon after, however, (*c.*15Kyr) cooler conditions seem to start and continue with minor breaks upto the mid-Holocene. During the mid-Holocene, the conditions warm up and after *c.*2500 B.P. the climatic became cooler again.[10] As there are not many ^{14}C dates for these bog profiles one does not have the desired resolution. From mid-Holocene onwards we have other pollen profiles from the Anchar and the Hokarsar lakes.

Here we would like to record that the anthropogenic interference during mid-Holocene is evidenced in the Anchar profile where *Cerealia* and *Plantago* pollen increase at the cost of aquatic plants. This probably indicates Neolithic agriculture as confirmed by the presence of wheat and barley grains from the Neolithic sites of Gofkral and Burzahom.

As the 18Kyr period is important from the global climatic point of view we would like to discuss it here in some detail.

Climate at 18Kyr

Globally *c.*18Kyr is supposed to be the period of glacial maxima, which is reported to be based on a variety of data both from land and sea. The deserts spread

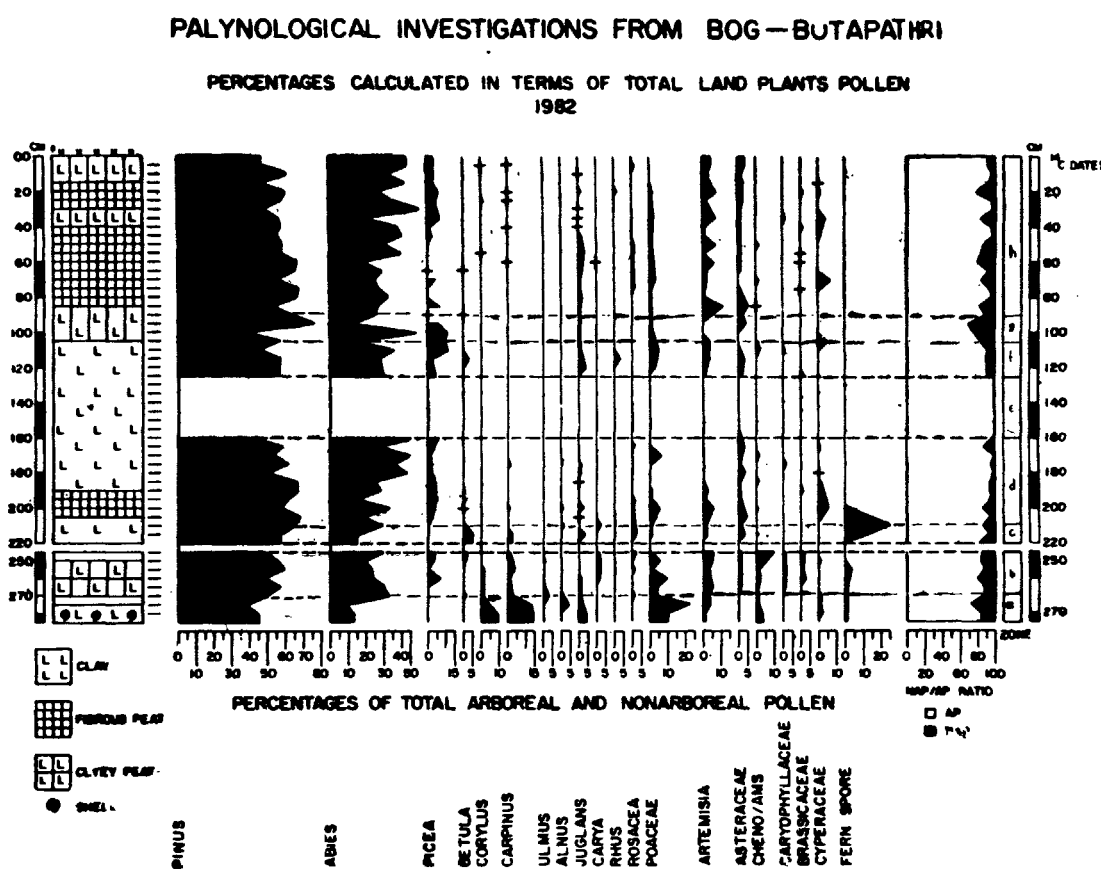

FIG 3 Pollen diagrams from Butapathri bog (Kashmir). Note the increase in broad leaved elments at the bottom of the diagram (^{14}C dated to *c.* 17 Kyr) at the cost of conifers, indicating an early warming up of Kashmir.

at *c.*18Kyr B.P. including the Thar desert. The polar faunal assemblages came down to middle latitudes. The sea surface temperatures became cooler by about 2 °C. Except for the lakes in the 40°N lat., other lakes show lower levels. Even in the Arabian Sea, *c.*18Kyr B. P. is marked by the heaviest $\delta^{18}O$ values for both planktonic and benthic foraminifera indicating coldest period.[17] In Rajasthan also we find that the period between 18,000–13,000 B. P. is marked by extreme aridity, spread of desert and hyper-salinity of the lakes[18] (Fig. 4). But in Kashmir warming up seems to start around 17Kyr B.P. as evidenced by Butapathri pollen profile.[6] On the basis of $\delta^{13}C$ measurements on the organic fraction of the palaeosols, Krishnamurthy *et al.*[13] have reported C-3 type of plants at *c.*18Kyr B. P. which is indicative of a climatic amelioration at this time in Kashmir. The development of an extensive palaeosol at this time itself indicates a climatic amelioration. In Kashmir where human settlements thrived only during optimum climatic conditions, one finds a large number of sites belonging to the Upper

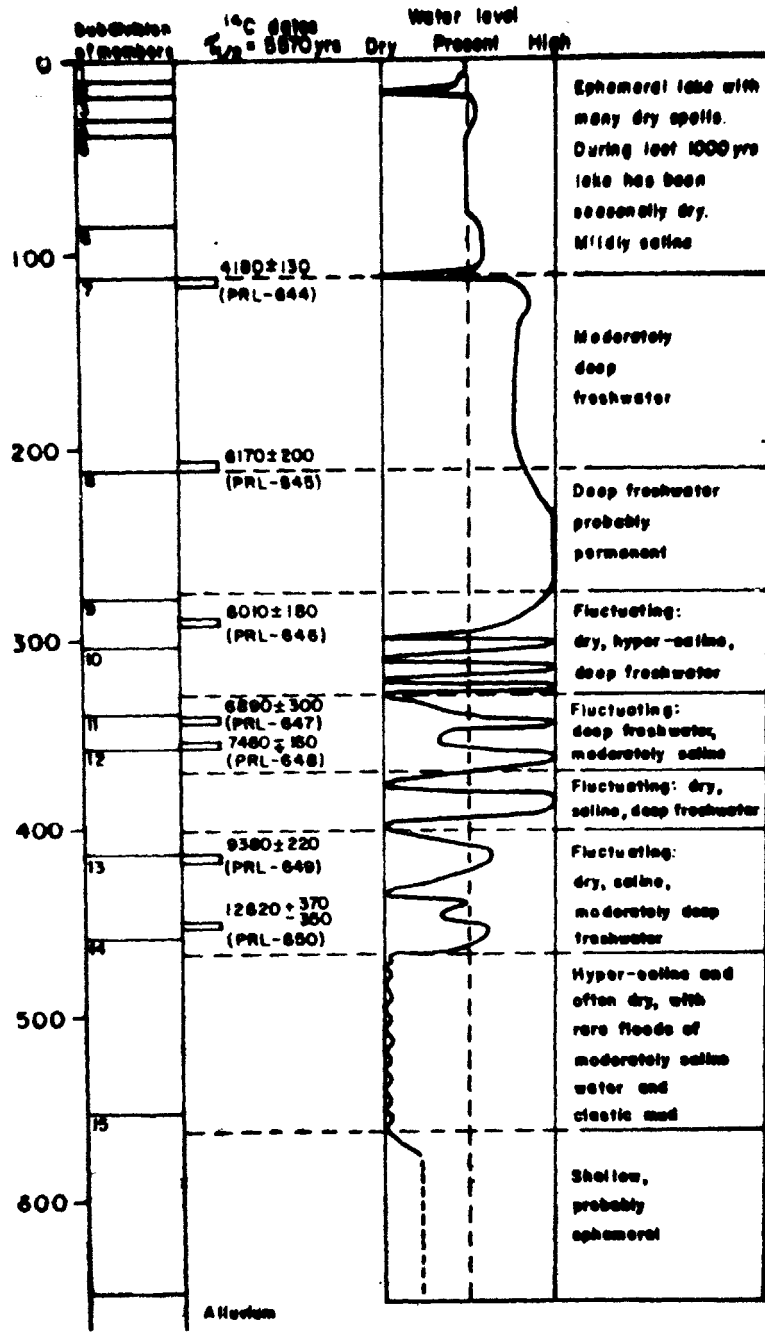

FIG 4 ^{14}C dated Didwana lake profile (Rajasthan) showing salinity variations with time. High water levels will show low salinity and therefore higher precipitation.[18]

palaeolithic (*c.*18Kyr), Neolithic (*c.*5Kyr), Kushana (*c.*1, 800 B. P.) and Mediaeval period (*c.*1000 A. D.) etc. Thus there was a marked correlation between increases in human population and climatic amelioration. Now the pollen data from Nepal and Japan[19] also show that deglaciation in this belt started before *c.* 20Kyr and *c.*18Kyr was definitely a warmer period and not the glacial maximum. At this latitude, as mentioned above, the lakes generally show higher levels at this period. It is possible that the Tibetan plateau which is also in this latitude, and has about 2.5 million km^2 land area jutting into the sky 4km high, has played some significant role in forcing the climatic change. The climatic amelioration therefore may be expected first in the areas closer to the Tibetan plateau. In any case, the gross global models of glacial maximum perhaps need to be corrected for regional variations and more realistic climatic models.

Climate at *c.*6Kyr

Well-dated climatic data are available only from Rajasthan and Kashmir. Between 6–4Kyr the Rajasthan lakes show hyper-salinity and salinity tolerant water vegetation in the pollen diagrams. During this period the Indus civilization also flourished. In Kashmir, on the other hand, there is a marked improvement in the *B/C* ratio as shown by Butapathri-II pollen profile.[10] In fact, the Butapathri-II profile covering the last 10Kyr shows very close resemblance to the Nepal pollen profile obtained by Yasuda and Tabata (this volume).

Conclusions

The Kashmir climatic record is not different from the global record if one allows for regional variations, time lags and tectonic factors. After the rise of the Pir Panjal to its present height, the SW monsoon does not affect the valley in any major way. The rise of the Pir Panjal is also responsible for the temperate climate of the Kashmir valley as it shields it from the heat and moisture coming from the subcontinent. Unfortunately, the record of various glaciations is not complete but several glaciations have already been discovered in Kashmir. The last 200Kyr of proxy climatic record from magnetic susceptibility also shows a general concordance with the global climatic record. During the last 20Kyr or so, though there is general concordance with the global climatic trends, the last deglaciation seems to have set in earlier than suggested globally. In the Holocene record also there is a three-fold change: cold-warm-cold which again broadly follows the global climatic changes.

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