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# Is it possible to demarcate floristically Pleistocene/ Holocene transition in India?

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Bhattacharyya A & Chaudhary V 1997. Is it possible to demarcate floristically Pleistocene/Holocene transition in India? *Palaeobotanist* 46 (1, 2) : 186-190.

The data on the floristic change during transitional phase of Pleistocene and Holocene are scanty. Although shifting of glacial to nonglacial climate is considered elsewhere for the demarcation of Pleistocene/Holocene, it could not be observed in India except at the glaciated sites in higher Himalayas. A major change can be traced in the nonglacial region due to strengthening of monsoon associated with higher insolation largely around this transition. Replacement of steppe by savanna in Rajasthan, increase in mangrove taxa in Arabian Sea sediments, decline of grassland with Shola constituents in Nilgiris, all happened under climatic change from arid to warm moist around 11,000-9,000 B.P. In the Himalayan region, at the higher elevations replacement of alpine taxa by subalpine birch has been noted in Kashmir and Himachal Pradesh during this transition, which is similar to Europe and North America where arctic elements are replaced by subarctic elements. However in Ladakh, the trans-Himalayan region, this transition is characterised by dominance of steppe taxa represented by Chenopodiaceae and *Artemisia* indicating aridity.

**Key-words**—Floristic changes, Palynology, Pleistocene/Holocene Boundary, India.

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## सारांश

क्या वनस्पतिजात के आधार पर भारत में प्लिस्टोसीन/होलोसीन परिवर्तन सुनिश्चित करना संभव है?

आमलव भट्टाचार्य एवं वन्दना चौधरी

प्लिस्टोसीन एवं होलोसीन कालीन परिवर्तन सम्बन्धी वनस्पतिजातीय आँकड़े बहुत कम हैं। यद्यपि प्लिस्टोसीन/होलोसीन सीमा सुनिश्चित करने लिए हिमानी से अहिमानी जलवायु को काफी महत्व दिया गया है, भारत में हिमालय के ऊँचाई पर स्थित स्थानों के अलावा अभी तक प्रेक्षित नहीं किये जा सके हैं। इस परिवर्तन के आस-पास अहिमानी क्षेत्र में एक मुख्य परिवर्तन सुनिश्चित करने का प्रयास किया जा सकता है। राजस्थान में स्टेप वनस्पति के स्थान पर सवाना, अरब सागर के अवसादों में मैंग्रोव वर्गकों की वृद्धि, नीलगिरि क्षेत्र में घासभूमि के स्थान पर शोला अवयव आदि सभी परिवर्तन लगभग 11000-9000 वर्ष पूर्व के आस-पास हुए जलवायु परिवर्तन के समय हुए हैं। हिमालयी क्षेत्र में अधिक ऊँचाई पर काश्मीर एवं हिमाचल प्रदेश में इसी परिवर्तन के समय अल्पीय वर्गकों के स्थान पर उप-अल्पीय बर्च वर्गकों का समावेश हुआ जो कि यूरोप और उत्तरी अमेरिका के समान है। तथापि, लद्दाख में हिमालय के पार वाला क्षेत्र स्टेप वर्गकों की बाहुल्यता व्यक्त करता है जिससे शुष्क परिस्थितियों का होना इंगित होता है।

IN reconstruction of floristic changes during the Quaternary, palynological data provide significant information. Macrofossils (fruits, seeds, leaves, cones and other plant fragments) can also be used to reconstruct floristic changes but such data are not available for the Late Quaternary. On the other hand, substantial palynological data have been generated which show floristic changes in time and space. The available data to demarcate any drastic floristic changes that may have occurred during the Pleistocene/Holocene (P/H) transition in India have been reviewed.

## GANGA PLAIN

There are many reports on geomorphological evidences demarcating Pleistocene and Holocene sequences (Singh & Mawar, 1992; Kumar *et al.*, 1996). Generally P/H transition could be recognised by changes from low sinuosity Late Pleistocene aggradational bed load stream to Holocene high sinuosity suspended load. This change has also been recorded in stratigraphic column by the fairly abrupt changes from coarse to fine sediments (William & Royce, 1982). Activation and formation of river channels and lakes were more active during 12,000

to 8,000 BP due to low sea level and increased water budget resulted from melting of glacier as well as high rainfall (Singh, 1996). Available pollen data are not sufficient to depict floristic scenario during this transition. Except few, most of the pollen data are derived from shallow cores or the sections having high sedimentation rate and thus having much younger dates, restricted within 7,000 BP (Gupta, 1981; Sen & Banerjee, 1990; Barui & Chanda, 1992). Palynological studies from a longer record indicate mangrove swamp conditions during last glaciation phase in lower Bengal Basin, but no data are available regarding floristic change around P/H transition (Chanda & Hait, 1996). A 2 m core was analysed from Bastua, Madhya Pradesh, which shows clear demarcation of sandy clay and organic mud at 1.7 metre (Chauhan, 1995). This zone may be dated around 10,000 BP since sediments at both upper and lower depths have been dated 8,710 BP and 11,550 BP respectively. During this period the area seems to be occupied by grassland under cool arid climate (Chauhan, 1995). However, drastic change in sediments from clay to organic mud may suggest depositional environment might be warm moist.

### RAJASTHAN

Palynological studies from the lakes of Rajasthan (Singh *et al.*, 1990) reveal that steppe, characterised by Chenopodiaceae/Amaranthaceae, grasses, *Artemisia*, *Aerva* and *Ephedra*, flourished during 20,000 to 13,000 BP. It indicates hyperarid climate when lake level was much lower due to weaker southwest monsoon; winter monsoon is believed to have been stronger than today. From 13,000 BP onwards, with intermittent increase in precipitation due to stronger summer and winter precipitation, steppe was replaced by shrub savanna grassland and, lake fluctuated from saline to fresh water. From 9,000 to 6,000 BP this savanna, in which *Prosopis* was a prominent tree element, flourished with the continuing amelioration of climate and higher lake level (Singh *et al.*, 1990). This increased lake level, evidenced by the rise of sedges, *Typha* and corresponding decrease of halophytic taxa, is also supported by the stratigraphic and geochemical evidences (Wasson *et al.*, 1984). However, Meher-Homji (1996) does not agree and opines that true indicators of wet phases are not seen in pollen diagrams; if these were there it should also reflect analogous deciduous forest of the Aravallis.

### SOUTH INDIA

Review of the palynological record starting from about 40,000 BP to recent from Nilgiri Hills (Gupta, 1990) and from 20,000 to recent from Palni Hills (Bera *et al.*, 1996) indicates that around 15,000 to 7,000 BP the climate was most favourable when close evergreen Shola forest dominated in this region. The Shola declined subsequently mainly due to human activities. Thus here P/H transition, marked by the close evergreen forest, comes under the bracket year of climatic optimum noted around 15,000 to 7,000 BP. The development of peak forest here does not coincide with the period of increased northeast monsoon during LGM (Sarkar *et al.*, 1990). This might be due to continued low temperature. However, its coincidence with the two phases of increased SW monsoon intensity during 13,000-12,000 BP and 10,000 to 9,000 BP (Overpeck *et al.*, 1996) might be due to associated higher insolation which reached maximum around 9,000 BP (Kutzbach, 1981). Analysis of  $\delta^{13}\text{C}$  values covering time span of last 20,000 BP from peats in Nilgiri Hills (Sukumar *et al.*, 1993) also provides additional support regarding existence of trees around this P/H transition. Generally  $\delta^{13}\text{C}$  values range from -24 per mil to -34 per mil in C3 plants in which mostly are trees and shrubs, and -6 per mil to -19 per mil in C4 plants which are mostly xerophytes. Thus any change in climate would reflect the values of  $\delta^{13}\text{C}$  in peat (Friedman, 1983). In the Nilgiri Hills during 20,000 - 16,000 BP there were mostly C4 plants indicating arid phase. From about 16,000 BP more negative signatures of  $\delta^{13}\text{C}$  indicating dominance of C3 vegetation have been noted and it reached optimum at around 10,600 BP (Sukumar *et al.*, 1993). However, in a latter observation this peak has been noted at around 9,000 BP (Rajagopalan *et al.*, 1997) which coincides with the peak of enhanced monsoon at 10,000-9,500 BP (Overpeck *et al.*, 1996).

### HIMALAYAN REGION

Except for a few, most of the palynological studies in this region have been made either from Late Holocene (Sharma & Chauhan, 1988; Chauhan & Sharma, 1996 a,b; Mazari *et al.*, 1996; Bhattacharyya & Chauhan, 1997) or covering only Pleistocene (Agrawal *et al.*, 1989).

### Lower Himalaya

Most of pollen diagrams are made from cores (4,000 BP to recent) from the western Himalaya from lake margin. Even from the available longer palaeoclimatic records from 52 m deep lacustrine sediment section from Naukuchia Tal, floristic scenario after 21,500 BP could not be reconstructed since corresponding sediments are found barren of pollen contents (Kotlia *et al.*, 1997). Thus, floristic signature during P/H transition remains unrepresented from the western Himalayas.

In the eastern Himalaya the P/H transition has been characterised by the formation of oak forest under amelioration of climate replacing arid phase characterised by Oak Savanna around 10,000 BP (see Chauhan & Sharma, 1996b).

### Higher Himalaya

There are several reports from this region which indicate drastic changes in lithology from fine clay to peaty or organic rich clay around 9,000 BP (Derbyshire & Owen, 1996; Sharma & Owen, 1996) which might be due to changes from glacial to nonglacial climate. The transition of fine grey clay to organic rich dark brown clay at Marhi (Bhattacharyya, 1988) seems to be contemporaneous development since it has a date of 8,000 BP, a few cm above this transition. Generally, peat or organic deposit has begun to form only after the last glacial period around 10,000 yr BP. Palynological data recorded from several sub-alpine sites, like Lake Rara National Park, west Nepal (Tabata *et al.*, 1988; Yasuda, 1988), and Kashmir Valley (Dodia *et al.*, 1985) also suggest that there were marked changes during P/H transition which are indicated, in general, by increase in broad leaved taxa at the expense of conifer taxa. Even in the simplified vegetational sequences made (Vishnu-Mittre, 1979) from the published pollen diagram of Toshmaidan, above tree limit, in Kashmir (Singh & Agrawal, 1976) show drastic decrease in conifer taxa especially around 11,360 to 10,000 BP. In the sub-alpine region, the replacement of alpine taxa by sub-alpine birch noted in pollen diagram made from Marhi, Himachal Pradesh (Bhattacharyya, 1989) seems to be analogous to Europe and North America where arctic elements are replaced by sub-arctic elements during this P/H transition.

### TRANS HIMALAYAN REGION

P/H transition is characterised by arid climate, as at present, in this region and is indicated by the dominance of Chenopodiaceae, *Artemisia*, *Ephedra* and other steppe taxa in the pollen diagram from Tsokar Lake, Ladakh (Bhattacharyya, 1989). Stable isotope studies for carbon and oxygen from calcium carbonate from lacustrine sediments from the same site also confirm it. Adjacent Tibetan Plateau was also arid during P/H boundary as evidenced by drastic increase of  $\delta^{18}\text{O}$  ratios around 10,000 yr BP (Thompson *et al.*, 1989).

### MARINE SEDIMENTS

Palynological studies from marine sediments from Arabian Sea have shown an increase in taxa which indicate enhanced monsoon during 13,000-12,500 BP and 10,000-9,500 BP. Enhanced monsoon during these periods is also corroborated by other proxy data (Overpeck *et al.*, 1996). The pattern of changes of monsoon as derived from pollen data in Rajasthan seems to be synchronous with these marine records. Moreover, these observations have been found to have close relationship with terrestrial records from Africa and other region of Asia (Anderson & Prell, 1993).

### DISCUSSION AND CONCLUSION

During the INQUA subcommission meeting 1961, major opinion favoured on fixing the P/H boundary in between the Younger Dryas and Preboreal, i.e., around 10,000 B.P. (Fairbridge, 1983). However, criteria considered elsewhere may not be applicable in India because of its diversified flora in response to varied climate ranging from tropical to alpine. At the lower elevation the impact of climate may not reach to threshold point for changing vegetation since only the Himalayan region were ice covered during the Quaternary. Due to interlinked climatic phenomena (Kutzbach *et al.*, 1993; Ruddiman & Kutzbach, 1989; Broccoli & Manabe, 1992), especially teleconnection in between monsoon and to extant of snow cover (Prell & Kutzbach, 1992; Kutzbach *et al.*, 1993), there is a great variability in monsoon. Thus, changes in floristics mainly due to limiting effect of precipitation from one site to other could also be visualised.

Floristic signatures around P/H transition in India may be unique in terms of influence and feedback action of climate, especially changes in temperature, monsoon and western disturbances, along with other physiographic and biotic factors during shifting of glacial to nonglacial environment. With the available pollen data, major changes across this transition can only be assumed in the Himalayan region where influences of glacial to nonglacial climate are obvious. In this region, migration of taxa of lower elevation to higher elevation could be expected with the change of climate. However, the interpretation of pollen diagrams from the montane region needs more attention because the presence of a large amount of pollen taxa from the lower elevation vitiates the pollen spectrum at high altitude. In such cases not only modern pollen/vegetation relationship which help to understand present day behaviour of flora in sediments, but quantification of pollen in sediment also needs to be determined through calculating pollen influx and absolute pollen frequency. No studies have been made from this point of view. In the lower Himalaya and other regions floristic changes noticed might be due to variable intensity of monsoon in relation to impact of changing of Himalayan snow cover. However, it has been observed that during last glaciation the development of forest under ameliorating climate has started much earlier around 16,000 BP and reached optimum around 11,000-9,000 BP in Rajasthan and in tropical montane. But in the Himalayan region it might have started much later and development of interglacial vegetation probably had started around 11,000 to 9,000 BP. It is apparent that the impact of deglaciation was earlier at the lower altitude sites than at higher elevation. In some analyses, although there were some indications of vegetational changes during this transition, proper emphasis was not placed on sampling for both palynological and C-14 datings. In such cases wide sampling and paucity of C-14 dates hampered the reconstruction of fine resolution pollen diagrams. For a detailed floristic scenario, macrofossil analysis side by side to pollen analysis should also be considered, but data in this regard is almost lacking. The basis for classifying Quaternary strata is primarily biological, however, radio isotope datings provided the time-frame to unravel the exact response of the floristic changes to climatic changes.

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