Did the Late Miocene Phase of Himalayan Orogeny Drive a Major Shift in India's Climate and Vegetation?

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Uplift of the Himalayan orogenic belt began as soon as the collision of the Indian and Eurasian plates took place at ~55 Ma ago. Since then, the Himalayan orogen has witnessed several phases of tectonic uplift, and the Himalaya attained a critical height to become a significant orographic barrier that set up an intense monsoonal climate, and consequently brought changes in flora and fauna of the Indian sub-continent. Besides changes in the sedimentological character of continental sediments, change in the photosynthetic pathway of plants on a large scale can reveal important information on the tectonic and climatic history of a region. In view of this, the objectives of the present work are (1) to reconstruct palaeovegetational and palaeoclimatic history from the isotopic study of Cenozoic Siwalik palaeosols in the Ramnagar sub-basin, (2) to examine observed similar palaeovegetational and palaeoclimatic changes, if any, in other parts of the Himalayan Foreland Basin (HFB) and (3) to correlate changes in palaeovegetation and palaeoclimate with the tectonic pulses in the late Cenozoic Himalayan orogeny.

We carried out carbon and oxygen isotope analyses of soil carbonate, largely nodules, from three Indian Siwalik sections: Jammu–Nandni, Purmandal-Uttarbehani and Samba-Mansar from Jammu & Kashmir state of India in the Ramnagar sub-basin covering a lateral stretch of ~40-50 km along strike (Figure 1a). The analysed samples cover a time range from mid-Miocene to late Pleistocene. In all the three studied sections, soil carbonate nodules were collected from the palaeosol horizons and their ages are assigned from ages of corresponding palaeosol beds, which are based on palaeomagnetic dating (Rao, 1993).

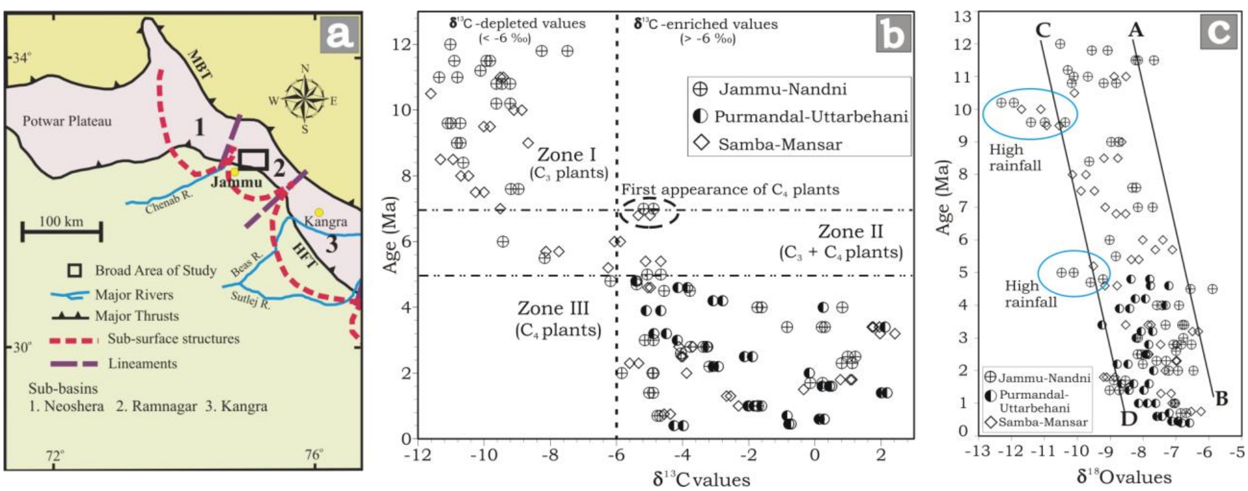

Figure 1 (a) Simplified geological map showing location of the present study in the Ramnagar sub-basin of the Himalayan Foreland Basin (modified after Raiverman, 2002). **(b)** Composite plot of $\delta^{13}C$ values against age from the studied sections. We divide the $\delta^{13}C$ values into two broad divisions; an older part characterized by $\delta^{13}C$ depleted isotopic values (< -6‰) and a younger part showing $\delta^{13}C$ enriched isotopic values (> -6‰) named Zone I and Zone III respectively. Zone I indicates the exclusive presence of C_3 plants whereas Zone III indicates the exclusive presence of C_4 plants. This change in vegetation with age from C_3 plants to C_4 plants spans a transition period, Zone II, in which both C_3 and C_4 plants have been found. Dotted ellipse marks the first appearance of C_4 plants at 7 Ma and 6.8 Ma in the Jammu-Nandni and Samba-Mansar sections respectively. **(c)** Composite plot of $\delta^{18}O$ values against age from the three studied sections. The $\delta^{18}O$ values are depleted from the normal AB-CD range at around 10 Ma and 5 Ma (marked by blue ellipses). These depleted values signify monsoon intensification during that time. The $\delta^{13}C$ and $\delta^{18}O$ values are expressed in per mil (‰).

Our results reveal that carbon isotopic record in the studied sections falls into two broad divisions, an older part (>7 Ma) characterized by $\delta^{13}C$-depleted isotopic values and a younger part (<5 Ma) consisting of $\delta^{13}C$-enriched values, respectively indicating exclusive presence of C_3 and C_4 plants (Figure 1b). This prominent change in vegetation from the primitive C_3 plants in mid-Miocene to C_4 plants in the late upper Miocene has also been reported in other parts of the HFB (Quade and others, 1989; Sanyal and others, 2004; and many more) and was first explained by Quade and others (1989) in the Pakistani and Nepali Siwaliks to be the result of intensification of Asian monsoon due to Himalayan uplift at ~10 Ma. Our oxygen isotope data also shows depleted $\delta^{18}O$ values from the normal AB-CD range at ~10 Ma and 5 Ma indicating an increase in rainfall or monsoon from the usual trend during that time (Fig. 1c). However, a time gap of ~5 Ma remains between complete vegetation change and monsoon intensification. Moreover, this late Miocene change in vegetation was a global phenomenon (Cerling and others, 1997; Selagen and others, 2007; and many more).

The Himalayan orogeny witnessed its greatest tectonic upheaval in the late Miocene (~10 Ma) as revealed by mean sediment accumulation rates in the HFB which have been derived from 56 magnetostratigraphic sections in the HFB (Sangode and Kumar, 2003), and this is well corroborated by much other geological evidence (Harrison and others, 1992; and many more). Even fluvial architecture changed markedly from minor to major multistoried sandstone bodies indicating an increase in channel dimension and discharge. Moreover, fossil evidence indicates that no significant physical barrier to migration of mammal faunas existed prior to the late Miocene (Wang and others, 1982). However, it seems monsoon intensification by this late Miocene tectonic uplift may not be a major cause for the prominent change in vegetation, but rather it seems more likely that increased chemical weathering due to late Miocene tectonic events resulted in a large-scale decrease in atmospheric CO_2 concentration (Raymo and Ruddiman, 1992) which finally prompted expansion of C_4 plants as they have a competitive advantage over C_3 plants when the ratio of atmospheric CO_2/O_2 concentration is low. Many workers have shown large-scale decline in atmospheric CO_2 concentration during the late Miocene (Spivack and others, 1993; and many more).

Hence the tectonic uplift of the Himalayan orogen during the late Miocene finally changed ancient tropical climate and C_3 vegetation of the Indian sub-continent to the present day monsoonal climate and C_4 vegetation.

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