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Late Holocene (~3 ka) Paleoclimatic Records from Baspa Valley, NW Himalaya: A Multi-Proxy Approach

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Abstract

We investigated a 83-cm-thick fluvio-glacial sedimentary profile from Baspa Valley, Central Himalaya, where monsoonal precipitation and glacial deposits are well preserved. We use a multi-proxy strategy to reconstruct Late-Holocene climatic variability in this region, including carbon isotope, environmental magnetism, total organic carbon, and AMS Carbon-14 dating. These multi-proxy data showed alternate warm and cool climatic phases that govern glacial snow melting and advancement, respectively. The current study revealed that the climate was warm and moist (deglaciation phases) from 2.9 to 1.5 ka and 1 to 0.5 ka. The warm and moist conditions in this area are characterised by depleted carbon isotope values, high organic production, and high magnetic mineral concentrations. The Indian monsoon conditions were very intense during this time period. Cold and dry climatic conditions (glacial phase) were recorded between 1.5 and 1 ka, as shown by carbon isotope enrichment, lower organic production, and low magnetic mineral concentrations. During this period, weak monsoonal conditions were observed in the Baspa region, Northwest Himalayan region.

Keywords: Palaeoclimate, Environmental Magnetism, Carbon Isotope, AMS 14C Dating, Baspa Valley, NW Himalaya

Introduction

Glacial deposits are one of the most reliable indicators of climate change. The short-term changes in snow/ice melting occur owing to warming in the climate and this climate signature is preserved in the form of annual layers in the glacial lakes and glacial outwash deposits whereas the long-term changes in the glaciers are reflected in the moraines deposits (Shukla *et al.*, 2020). Recent studies on the moraine and glacial lake deposits shows that the quality and reproducibility of the glacial variations during the Holocene have significantly increased in the Himalayas (Shukla *et al.,* 2020; Meena *et al.,* 2022; Lone *et al.,* 2022; Khan *et al.,* 2022; Khan, 2023; Sagwal *et al.,* 2023; Meena *et al.,* 2024). Hence, high-resolution climatic studies using glacial deposits are very significant to understand the glacial/deglacial patterns in the Himalayas related to climate change.

The Himalaya plays a significant role in influencing the climate across the northern belt of the Indian sub-continent. Long-term climatic change is influenced by the unique characteristics of Indian orography in the Northwestern Himalaya, which alters the pattern of precipitation over the area (Shekhar *et al.*, 2010). Mid-latitude Westerlies (MLW) and the Indian Summer Monsoon (ISM) are the principal precipitation producers in the Himalayas. On a millennial to decadal timescale, the ISM and MLW variations have historically governed the changes in Himalayan glaciers (Benn and Owen, 1998). The precipitation trend normally declines from East to West because the ISM trough gets smaller as it advances towards the west along the Himalayan mountain range (Bookhagen and Burbank, 2010). The eastern Himalaya receives precipitation that is primarily brought on by the ISM. In the western Himalaya, MLW contributes about 2/3rd of the annual precipitation in the form of high-altitude snowfall during winters, with the remaining 1/3rd coming from precipitation primarily due to ISM in the summer (Armstrong, 2010). It is difficult to comprehend the climatic mechanisms that generate natural catastrophes in the Himalayan area as a result of these complicated weather phenomena (Rana *et al.,* 2021a, b; Agarwal *et al.,* 2022). Since the first climatic study at Baspa (Sangla) Valley, Northwest Himalaya (Ganjoo and Koul, 2005), several investigations have been performed to reconstruct Late Quaternary to Holocene climate (Chakraborty *et al.,* 2006; Ranhotra and Bhattacharyya, 2010; Ranhotra *et al.,* 2018; Khan *et al.,* 2022; Khan, 2023) and glaciers fluctuation (Bhattacharyya *et al.,* 2006; Draganits *et al.,* 2014a, b; Dutta *et al.,* 2018; Ranhotra *et al.*, 2022). The Karu, Jorya, Janapa, Naradu, Magsu, and Shushang are the

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