Impact of Anthropocene Vis-à-Vis Holocene Climatic Changes on Central Indian Himalayan Glaciers

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Impact of Anthropocene Vis-à-vis Holocene Climatic Changes on Central Indian Himalayan Glaciers

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Rameshwar Bali, S. Nawaz Ali, S.K. Bera, S.K. Patil, K.K. Agarwal and C.M. Nautiyal

Abstract

Systematic palaeoclimatic study of the glacio-lacustrine sediments using multiproxy data in Pindari glacier area, Central Himalaya has helped in better understanding of the climatic fluctuations since the last 7 Ka. The palynological data supported by the environmental magnetic parameters suggests that the climate of the Pindar valley was cold and dry during 7 ka BP followed by five different vegetational shifts. The studies further suggest that since the last 300 yr BP, the climate has been warm and moist. It has to be ascertained weather the present phase of warming as inferred from the current phase of deglaciation is anthropogenic or is the continuation of the warm period that was initiated prior to the anthropocene time around 300 years B.P.

Keywords

Holocene • Palaeoclimate • Central Himalayan glaciers • Anthropogenic

89.1 Introduction

The Himalaya and Tibet, the most glaciated regions outside the poles, have influenced the regional and global environmental change. In spite of the importance of Himalayan glaciation, the nature of late Pleistocene and Holocene glaciation in the region is poorly understood. The geomorphological setup of the Higher Himalayan region suggests that these areas have experienced phases of glaciations as well as deglaciation in the recent geological past (Sharma and Owen 1996; Pant et al. 2006; Nainwal et al. 2007; Bali et al. 2013). The process of deglaciation, similar to the present one, is believed to have taken place a number of times in the past as well. Although most of the studies indicate multiple events of glaciations in the Himalaya, however, the quantitative estimate on their timing is lacking due to scarcity of organic material that precludes the use of standards radiocarbon-dating techniques (Owen 2009; Owen et al. 2002).

The present work is based on the studies carried out along the upper reaches of Pindari glacier basin, central Himalayan region. The basin located in the upper reaches of Bageshwar District of Uttarakhand, has an area of 632.67 km^2 (Fig. 89.1). The Pindari basin is constituted of the Central Crystalline rocks of the Higher Himalaya. Geomorphologically, the area is constituted of a number of erosional and depositional landforms that seem to have been influenced by neotectonic activity (Bali et al. 2012).

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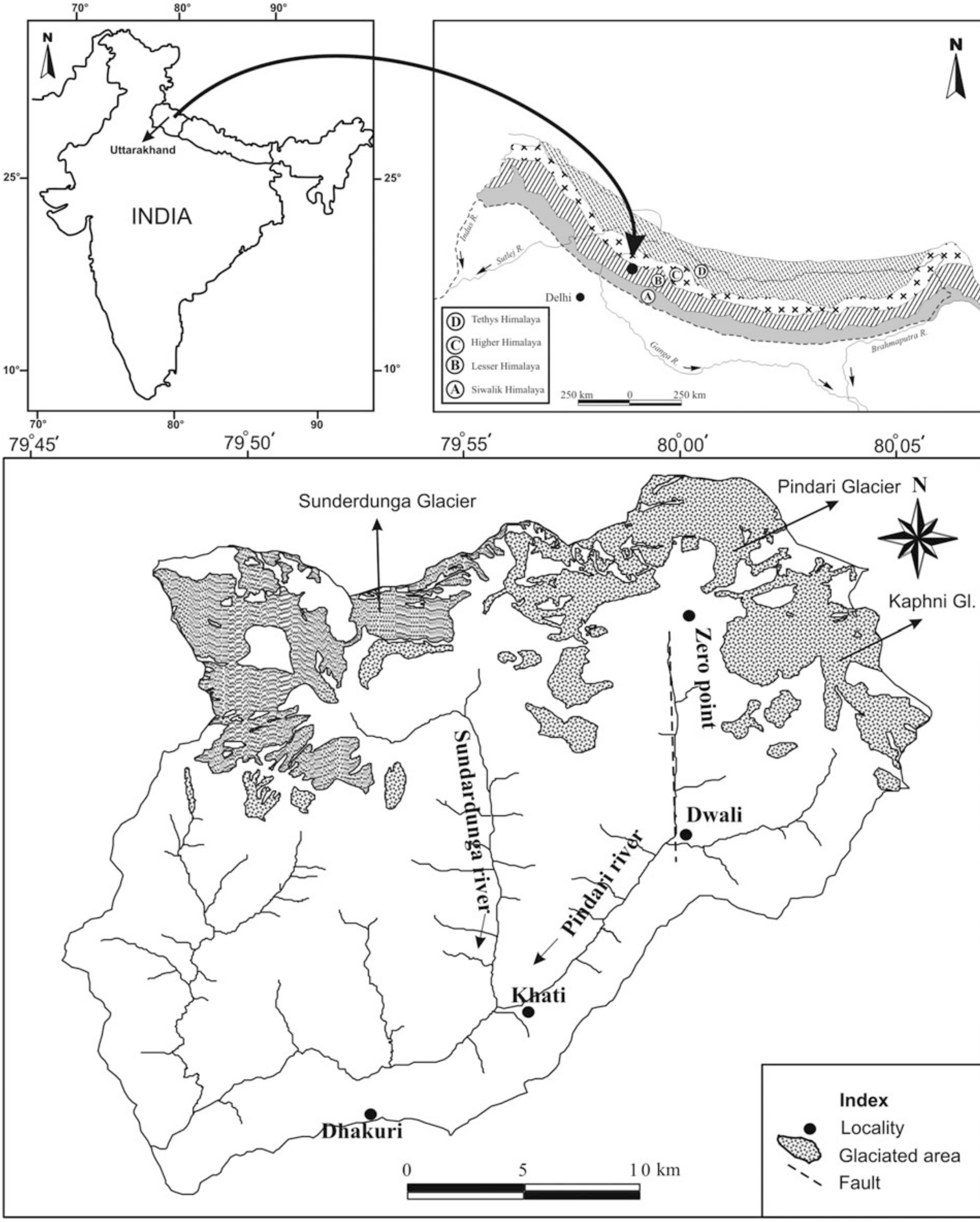

Fig. 89.1 Location of the study area

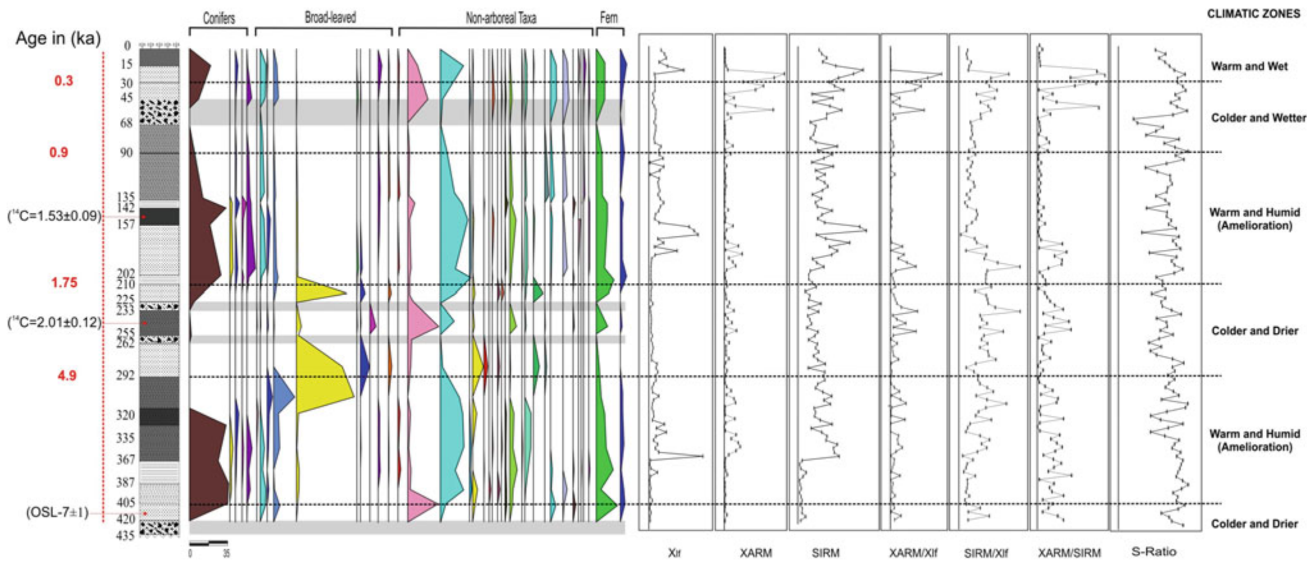

Fig. 89.2 Climatic zones as deduced from the pollen and magnetic data. Both the parameters show a good correlation

89.2 Palaeoclimatic Reconstruction

In order to have a better understanding of the Holocene climate changes, multi proxy studies including establishing the moraine stratigraphy using geomorphological studies, carrying out palynological, environmental magnetic, remote sensing and GIS studies and geochronology using optical dating has been carried out. Samples for Palynological and mineral magnetic studies have been collected from the 435 cm pit excavated within a kame deposit located in between the depression of two left lateral moraines (30° 15′ 36″ N and 79° 59′ 52″ E). The area lies about 4 km above the present day tree line and the vegetation around the area is of alpine meadow type. A total of 16 samples throughout the vertical extent of the 435 cm pit profile have been analysed for palynological analysis.

89.2.1 Mineral Magnetic Studies

Magnetic measurements of the samples have been carried out using Bartington MS-2B Susceptibility meter at Dr. K. S. Krishnan Geomagnetic Research Laboratory, Jhunsi, Allahabad. A total of 118 samples throughout the vertical extent of the pit profile were taken in 2 × 2 × 2 cm cubical non-magnetic samplers for environmental magnetic studies. The environmental magnetic measurements including low field magnetic susceptibility, Anhysteretic Remanent Magnetization (ARM), Isothermal Ramanent Magnetization (IRM) and hysteresis parameters have been determined using the standard procedure (Dekkers 1997; Evans and Heller 2003; Peters and Dekkers 2003).

Anhysteretic **(ARM)** and isothermal **(IRM)** remanent magnetization mostly reflect changes in magnetic concentration within the sediment. The Low frequency magnetic susceptibility **(χ_{lf})** shows peaks of high χ_{lf} and troughs of low χ_{lf} throughout the pit profile. All along the vertical extent of the 435 cm deep pit, the low frequency magnetic susceptibility **(χ_{lf})** shows three major peaks and four troughs (Fig. 89.2). The fluctuations in the χ_{lf} in the glacio-lacustrine deposit are modulated by climate (Verosub and Roberts 1995).

The three peaks in the χ_{lf} graph are indicative of relatively higher concentrations of ferromagnetic minerals. These peak values may be due to warmer climatic conditions prevailing during that period. Warmer periods provide higher weathering conditions of the country rocks and deposition of good amount of sediments resulting in the higher concentration of iron minerals.

The anhysteretic susceptibility **(χ_{ARM})** and Saturation Isothermal Remanent Magnetization (**SIRM**) indicate higher concentration of Stable Single Domain (**SSD)/** Pseudo Single Domain **(PSD)** type ferromagnetic minerals thereby indicating deposition to have taken place during warmer climatic conditions.

89.2.2 Palynological Studies

In the present investigation the interpretation of the climate is based on the fluctuation in the representation of pollen assemblage comprising conifers, broad-leaved taxa and alpine-subalpine non-arboreal complex (Fig. 89.2). The pollen inferred vegetation scenario together with comparison with the magnetic susceptibility results of the pit profile has been divided into six distinct zones (PG-I, PG-II, PG-III, PG-IV, PG-V and PG-VI). The pollen zones have been prefixed with 'PG' after the name of the site of investigation (Pindari Glacier). The study is aided with two ^{14}C and one OSL dates indicating that the sedimentation of this Glacio-lacustrine deposit has initiated prior to 7 ka BP.

The climate for the region has been worked out to be cold and dry during 7 ka BP followed by five different vegetational shifts. The vegetation complex as marked by high conifers associated with broad leaved as well as herbaceous taxa and high magnetic susceptibility suggests the amelioration of climate during 7–4.9 ka BP. Thereafter, during 4.9–1.75 ka BP, the climate once again shows cold and drier condition as evidenced by acceleration of alpine herbaceous taxa with gradual decrement of conifers and broad leaved taxa. However, during 1.75–0.9 ka BP, the climate seems to have become relatively warm and moist (~Medieval Warm Period) as evidenced by the presence of both conifers and broad leaved taxa along with fair amount of *Rhododendron*. During 0.9–0.2 ka BP, a drastic climatic change has been witnessed (~Little Ice Age) as evidenced by the relative decline in conifers and broad leaved taxa except *Quercus* and *Rhododendron*. The sediments of this zone also show lower values of the magnetic susceptibility. Since the last 300 yr BP onwards, the vegetation complex including conifers, broad leaved taxa along with herbaceous elements along with high magnetic susceptibility indicates warm and moist climatic regime. The presence of cereals (>60 μm) along with culture pollen like Tubuliflorae, Acanthaceae, Caryophyllaceae and Polygonaceae also support the high pastoral activity during this phase. Further, the steady presence of both monolete and trilete fern spores suggest an overall warm and moist climatic condition as prevailing presently in and around the study area.

89.3 Discussion and Conclusions

Holocene climatic data as recorded from the palynological and environmental magnetic proxies from the Pindari glacier valley located in the higher central Himalayan region, suggests that this region has experienced at least six major climatic shifts during the last 7,000 years. The study further suggests that in the (central) Himalayan region, the present phase of warming started almost 300 years BP and seems to have been continuing since then, prior to the beginning of the time of industrial revolution i.e. Anthropocene.

There seems to be a general view, that of late, the Himalayan glaciers have been showing alarmingly high rate of melting and recession. Such an activity is suggested to have been caused due to the anthropogenically induced climatic changes. Systematic field observations taken during the last several decades for few selected glaciers in the central Himalayan region shows that although the glaciers have been receding, the rate of recession has in fact been reducing. Field observations for the Pindari glacier located in the Kumaun Himalaya reveals that the rate of recession for this glacier has come down from 26.50 m/yr recorded during 1845–1906 AD to 6.5 m/yr during 1966–2007. However, the later observations show a sudden rise in the rate of recession between 2007 and 2010 (Bali et al. 2013). On the other hand, the rate of recession for the Gangotri glacier (largest in the central Himalayan region) recorded between 1935–1971 AD has also come down to around 12 m/yr during 2004–05 AD (Bali et al. 2011).

Thus the present phase of warming that started almost 300 B.P. is a natural cycle of warming or has resulted due to anthropogenic activity has yet to be ascertained. It is believed that more such scientific inputs and proxies including geochemistry of lacustrine deposits, ice core studies, dendrochronology etc. are required from different parts of the Himalaya to have better understanding of the Holocene climatic changes vis-à-vis impact of anthropogenic activity on the current climate change.

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