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Tree ring analysis of *Abies pindrow* around Dokriani Bamak (Glacier), Western Himalayas, in relation to climate and glacial behaviour: Preliminary results

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ABSTRACT

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Analysis of tree ring data of *Abies pindrow* has been made from seven sites (Din Gad Valley) close to the Dokriani Bamak Glacier (Latitude 30°50' to 30°52' N and 78°47' to 78°50' E Longitude). Total 299 cores from 157 trees were collected from seven sites representing different glacially formed geomorphic features and elevation zones to study growth behaviour of trees in relation to climate change and glacial fluctuations in the Western Himalaya. A tree ring chronology of this site for the last 371 years extending from 1625 AD to 1995 AD has been established. Analysis of tree growth trend during this period indicates that the trees of this region experienced several periods of reduced growth that might have coincided with positive mass balance and glacial advance.

Key-words—*Abies pindrow*, Glacial fluctuations, Tree-rings.

पश्चिमी हिमालय के डोकरियानी बामक (हिमनद) के आस-पास की जलवायु एवं हिमनदीय प्रकृति विवेचना हेतु *एबीज़ पिण्ड्रो* का वृक्ष वलय विश्लेषण

अमलव भट्टाचार्य, वन्दना चौधरी एवं जे.टी. गरगन

सारांश

डोकरियानी बामक हिमनद (30°50' से 30°52' उत्तरी अक्षांश पर तथा 78°47' से 78°50' पूर्वी रेखांश) के समीपस्थ सात संस्थितियों (दिन गाद घाटी) से *एबीज़ पिण्ड्रो* के वृक्ष वलय आंकडों का विश्लेषण किया गया। पश्चिमी हिमालय में जलवायुविक परिवर्तनों तथा हिमनदी उच्चावचनों के सन्दर्भ में वृक्षों की वृद्धि के रूझानों के अध्ययन हेतु भिन्न-भिन्न हिमनदीय रूप वाले भूआकृतिक स्थलों को निरूपित करने वाली सात संस्थितियों तथा ग्यारह मण्डलों से कुल 157 वृक्षों से 299 क्रोड एकत्र किए गए। विगत 1625 ई. से 1995 ई. के मध्य के 371 वर्षों का इस वृक्ष का कालानुक्रम निर्धारित किया गया। इस काल का वृक्ष वृद्धि रूझान विश्लेषण इंगित करता है कि इस क्षेत्र के वृक्षों में अल्प वृद्धि के अनेक चरण इस दौरान आए होंगे, जो सकारात्मक सन्तुलित पुंज तथा हिमनदीय अग्रता के साथ सम्पाति होंगे।

संकेत शब्द—*एबीज़ पिण्ड्रो,* हिमनदीय उच्चावचन, वृक्ष वलय.

INTRODUCTION

EVIDENCE of advancement and retreat of glaciers are significant indicators of past climatic changes. A good amount of work (Jangpangi & Vohra, 1962; Kurien & Munshi, 1972; Vohra, 1981; Chaujar, 1991; Kumar & Dobhal, 1994; and others) has been done on Himalayan glaciers, which document geomorphic evidences of glacial fluctuations. However, constrain in these studies is lack of absolute dates of these features to provide temporal records of glacial fluctuations. Mass balance data selected from a glacier for a long period of time provides sufficient information to make a climatic classification for this region. This type of information is not available for Himalayan glaciers since most of the work on mass balance in the country has been aimed to calculate the net balance of glacier. Even, the mass balance data covering more than 10 years are not available.

In this paper, attempt has been made to discuss dendrochronological potentiality of *Abies pindrow*, a conifer growing in sub-alpine forests of which upper limit is located 800 m downstream from the snout of Dokriani Bamak Glacier. Tree-ring data of this species has been analysed to study relationship of tree growth with climatic changes of this region and glacial fluctuations. This data has also been used to give an approximate date of geomorphic features, which are indicative of glacial fluctuations during the recent past.

LOCATION OF SITE AND MATERIALS

Dokriani Bamak Glacier is a valley type of glacier situated between Lat. 30°50'-35°52' N and Long. 78°47'-78°50' E. It has a glacier area of 7·0 sq km and lies in Uttarkashi District, Uttaranchal State. It is 25 km east of Bhukki Village and nearly 60 km south of Gangotri (Fig.1). Most of the glaciated area in Din Gad Valley is now covered largely by silver fir (*A. pindrow*) intermixed with *Betula utilis* and *Rhododendron* near the timberline broad leaved mixed conifer forest in lower levels.

Tree-ring samples were collected during 1995 field trip mainly from silver fir growing on several glaciated features hundred to several hundred meters below the present position of the snout. A small number of samples of *Pinus wallichiana*, *Taxus baccata* and *Cedrus deodara* growing at lower elevation close to Tela have been collected to understand their suitability for tree ring analysis. Details of sampling sites are:

1. 800 m downstream from the present position of the glacier snout.

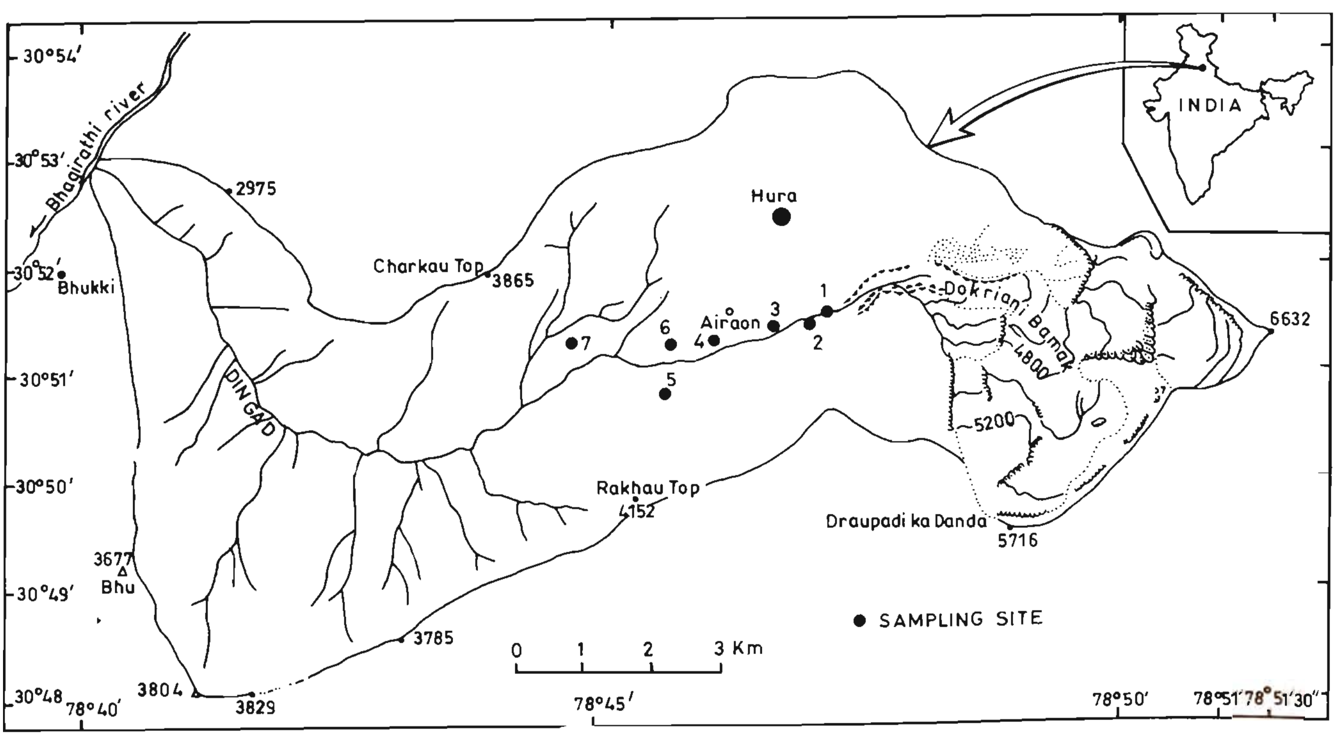

Fig. 1—Location of tree ring sampling sites around Dokriani Bamak Glacier.

2. Island in Din Gad 1600 m downstream from the glacier snout.

3. Palaeo medial moraine of Dokriani Bamak and Hura Glaciers.

4. Trees growing along the margins of marshy meadows of Khera Tappar.

5. Trees growing on northern rocky slope of Rakhau close to the Gujarhut Karauli.

6. Trees growing on margins of meadows on the way to Khera Tal.

7. Trees growing along a lateral moraine close to Khera Tal.

Generally, two cores per tree, one each from opposite direction were collected with the increment borer. Human disturbance is evident throughout the valley region but it is more conspicuous especially around Gujarhut at 3,000 m. Several left-over stumps and the presence of a few hollow trees of huge girth, which have escaped logging, indicate tree felling was common in the recent past.

TREE-RING DATING AND CHRONOLOGY PREPARATION

Samples were mounted and processed using standard procedure of tree ring analysis. Details of the methods of tree ring analysis is published in Stokes and Smiley, 1968; Fritts, 1976; Schweingruber, 1988; Cook & Kairiukstis, 1990; Hughes *et al.*, 1982 and others. Boundaries of rings in these trees are very sharp and neither false rings nor missing rings were recorded. All the samples except from trees growing at lower elevation of 2,500 m asl (Tela) have been dated by 'cross-dating' technique of tree-ring analysis. Oldest dates for these seven sampling sites in descending order are 1858 AD, 1828 AD, 1727 AD, 1704 AD, 1626 AD, 1781 AD and 1593 AD respectively. It has been observed that trees growing over thick soil cover around Khera Tal and Gujarhut are much older. In higher elevation closer to the glacier snout, trees are younger in age. For further analysis, ring widths of each dated core were measured using increment-measuring stage coupled with a microcomputer with 0·01 mm accuracy. These data have been analysed using COFECHA Program (Holmes, 1996). This program performs data quality control by thoroughly checking the tree ring measurements and locating all the portions within a tree ring series showing weak or erroneous cross-dating or measurement errors. Ring width data were standardised to form tree ring indices using program ARSTAN Program (Holmes, 1996). It removes growth trends related to age and stand dynamics while retaining the maximum common signal. Finally, tree ring chronology of this species from seven sites in Din Gad Valley has been established which extends from 1625 AD-1995 AD (Fig. 2).

CLIMATE AND GLACIAL DATA

Long climatic records around Dokriani Bamak Glacier are not available. Regular meteorological monitoring was started only few years back, which is not enough for the detailed analysis of the climate glacier relationship of the region. Even in the Himalayan region in general, the meteorological stations are very few and are situated mostly at lower elevations. This makes it difficult to use the meteorological data for the study of glacial fluctuations. However, a broad idea of the climatic trend (especially for temperature and precipitation) can be visualised at higher elevations during years of positive glacial mass balance reported earlier (Puri *et al.*, 1995) form the climatic records of several stations located at mid-elevations in the Himalaya. Analyses of data from published records (Pant *et al.*, 1999) from these stations indicate that at the beginning of the 20th century, i.e. during 1900 to 1930, summers were much cooler and winters were moist with a peak during 1905-1910. Low winter temperature and higher precipitation has been recorded during 1974-75, 1975-76. Regarding earlier positions of the snout of Dokriani Bamak Glacier relevant information only is available from the Survey of India topographical sheet

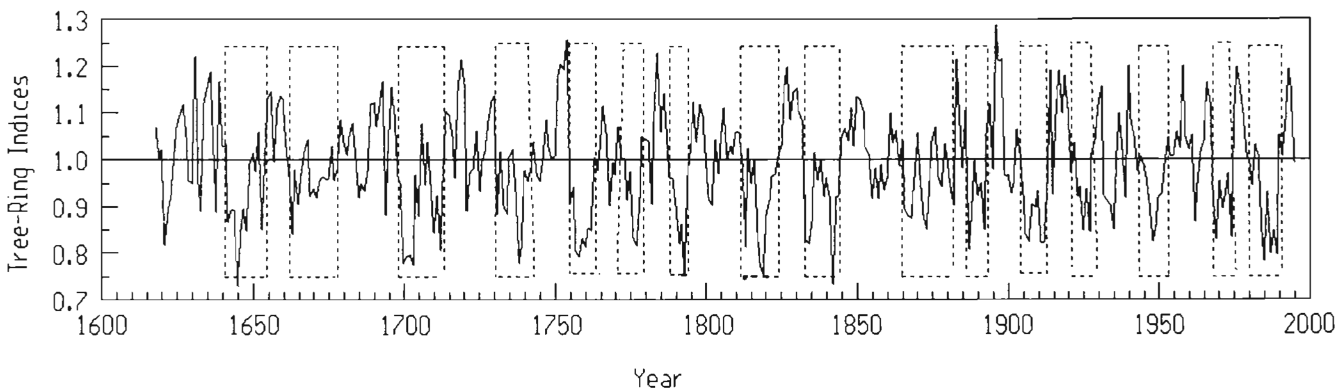

Fig. 2—Tree-Ring Chronology of *Abies pindrow* extending from 1625 to 1995 A.D. (Dotted area shows years of low growth).

(1962-63 edition) on a scale of 1:50,000. In the recent study by Gergan and Dobhal (1996), the total retreat of this glacier between 1962 and 1991 was calculated to 480·1 m (16·5 m/yr average) while during 1991 to 1995, it retreated by 69·9 m (17·5 m/yr average). This glacier like other Himalayan glaciers is in the state of recession during the recent past. There is little information regarding temporal aspects of the history of Himalayan glaciers. Mayeswki and Jeschke (1979) documented year-wise fluctuations of glaciers since 1812 AD, which is based on the percentage of advancement, retreat and stationary positions of several glaciers in the Himalayas and Trans Himalayan region. Until now this is the only report, on glacial fluctuations in terms of absolute dates, from this region.

TREE GROWTH/CLIMATE/GLACIAL FLUCTUATION

Most of these trees have been dated in between 1700 AD and 1995 AD, with the exception of some older trees growing around Khera Tal and Gujarhut at lower elevations are dated before 1700 AD. Absence of older trees might be due to unsuitable climatic conditions prior to eighteenth century for settlement of fir trees at these sites. Oxygen isotopic analysis from ice core of this glacier and surface snow samples suggest that climatic conditions three centuries ago, during the Little Ice-Age period, were much cooler than at present (Nijampurkar *et al.*, 1996).

Year-wise variations of tree growth and their relationship to corresponding year's glacial fluctuation or to the glacial mass balance budget and climate are very complicated. Several non-climatic variables play a significant role in both tree growth and budget of glacial mass balance. However, it is obvious that major climatic conditions required for tree growth and glacial advancement in the mountainous region are inversely related. High winter snowfall and short, cool, cloudy summers generally favour positive mass balance, which on the other hand retard tree growth by inhibiting photosynthetic activity during the growing period of a tree.

The growth behaviour of *A. pindrow* has been compared with the available data on glacial fluctuations, mass balance, precipitation and temperature data of the western Himalaya. Due to non-availability of modern climate data close to the glacier, it has not been possible to analyse tree growth trend in relation to the history of the present glacier. According to available data on glacial fluctuations (Mayewski *et al.*, 1980) and mass balance data of the western Himalayan region (Puri *et al.*, 1995), it has been observed that low tree growth occurs during advancement of glacier and positive glacial mass balance. The years of positive glacial mass balance reported by Puri *et al.* (1995) has been found within the bracket years of low tree growth recorded during 1968-76 and 1981-89.

Tree ring samples from trees growing about 1 km downstream to the glacier snout at 3,600 m. asl. have been dated to 1858 AD, which indicates that at least since that period the snout was higher than the position of trees dated and had not descended lower than the present position of this tree. It is a general observation that cold winds blowing from the glacier play a significant role in reducing the growth of trees in the vicinity. This impact would be more in case of an advancing glacier and could be seen in the growth pattern in trees growing several hundred meters below. These fluctuations might have caused lower tree growth for a considerable period by reducing the growing period. Several periods of suppressed growth lasting for five or more years recorded in the present *Abies* chronology might be linked with glacial advancement or years of positive glacial mass balance. Periods of suppressed growth are noticed during 1640-55, 1662-78, 1698-1713, 1731-42, 1755-64, 1771-80, 1786-94, 1811-24, 1832-44, 1865-82, 1885-94, 1904-13, 1921-29, 1943-53, 1968-76 and 1981-89 in the 371-years tree-ring chronology (Fig. 2). It is significant to note that the lower tree growth during the decade of 1810's might also be associated with the cooling of the Northern Hemisphere temperature resulted due to the eruption of Tambora in April 1815.

CONCLUSION

A. pindrow growing adjacent to snout of Dokriani Bamak Glacier has been found promising for tree ring studies to understand past glacial behaviour. Several periods of suppressed growth in the tree ring chronology covering 371 years seem to correspond to years of positive glacial mass balance of the near-by glacier during this period. Comparative analysis of tree growth with the available fragmentary data on glacial history and mass balance of Himalayan glaciers gives evidence on the interrelationship between mass balance budget and vis-à-vis climatic changes of the Himalayan region. Earlier, another sub-alpine conifer, *Pinus wallichiana* growing in Kinnaur, Western Himalaya, has also been found to have potential for this kind of study (Bhattacharyya & Yadav, 1996). The present study is not substantial; a detailed study is being taken up in the second phase of this work and by using multiple tree-ring chronologies of several conifer taxa of the sub-alpine region and using climatic data from a large number of meteorological stations which would provide a better data base to quantify tree growth/climate/glacial relationship in a longer time scale.

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