RELATIVE DATING OF MORAINES BY LICHENO-METRIC AND SCHMIDT HAMMER TECHNIQUES IN THE GANGOTRI GLACIER VALLEY, UTTARKASHI DISTRICT, UTTARANCHAL

DIVYA DARSHAN AWASTHI, RAMESHWAR BALI and N. K. TEWARI
DEPARTMENT OF GEOLOGY, UNIVERSITY OF LUCKNOW, LUCKNOW-226007

ABSTRACT

Lichenometric and Schmidt Hammer techniques have been used for relative dating of moraines in the Gangotri Glacier Valley, Uttaranchal. Five ground/recessional moraines have been studied in the area between Gaumukh and Bhojbas. Based on the known ages of two moraines (1935 AD and 1900 AD), the relative ages of two moraines on the downstream side have been computed as 1897 AD and 1881 AD by lichenometric technique on the basis of the growth rate of lichen *Dimelaena oreina*. The relative age of another moraine on the upstream side (devoid of the lichen *D. oreina*) has been established as 1970 AD by the Schmidt Hammer technique.

Key words: Gangotri Glacier, Moraine, Lichenometry, Schmidt Hammer, Dating techniques.

INTRODUCTION

The Gangotri glacier in the Uttarkashi district, Uttaranchal, is one of the largest valley glaciers in India and exhibits several geomorphic features, viz. lateral, terminal, recessional moraines, fluvio-glacial terraces, debris cones, etc. (Auden, 1935; Bali *et al.*, 2003). The morainic material, on which lichens generally grow, can be dated using lichenometric techniques. Lichenometric techniques, initiated by Beschel (1950), were further refined and applied by many workers for dating rock surfaces in several parts of the world (Beschel, 1961; Porter, 1981; Gordon and Sharp, 1983; Innes, 1986). In the glaciated regions, the technique is based on the assumption that the morainic material is devoid of lichens at the time of deglaciation, and only after a certain period of time the lichens begin to grow on the surfaces. The diameter of the thallus of the individual specimen increases progressively with the passage of time. Thus, the size of the thallus is proportional to the period of its growth.

Species having a nearly circular outline are preferred, as the technique involves measurement of the diameter of the thallus. For a particular species, the maximum sizes of the thalli on different surfaces of known ages are used to obtain a growth rate. The age of an undated surface can be found by measuring the diameter of the largest thallus of the same species on that surface, and correlating it with the growth rate obtained earlier.

Since each lichen species has a time lag before it colonises the rocks, Lichenometry is inapplicable for the dating of young moraines on which the lichens have not appeared as yet. In these cases, the Schmidt Hammer techniques may be used (Matthews and Shakesby, 1984; Evans *et al.*, 1999).

Based on the assumption that the boulder surfaces progressively weather with time, the Schmidt Hammer has been used by many workers to determine the age of the glacial deposits. The Schmidt hammer, initially

designed for *in situ* testing of surface hardness of concrete and later adopted for determining the hardness/ strength of rocks in the field, measures the rebound distance for a controlled impact on a rock surface. The rebound value (R) reflects the surface hardness/ strength of the rock and is indicative of the relative weathering of the rock material with time.

PRESENT STUDY

In India, lichenometric studies were first undertaken in the Gangotri area in 1976 (see Srivastava *et al.*, 2001). In the present study, investigations have been carried out in the Gaumukh - Gangotri area (fig. 1), and Lichenometric / Schmidt Hammer dating techniques have been attempted on five of the
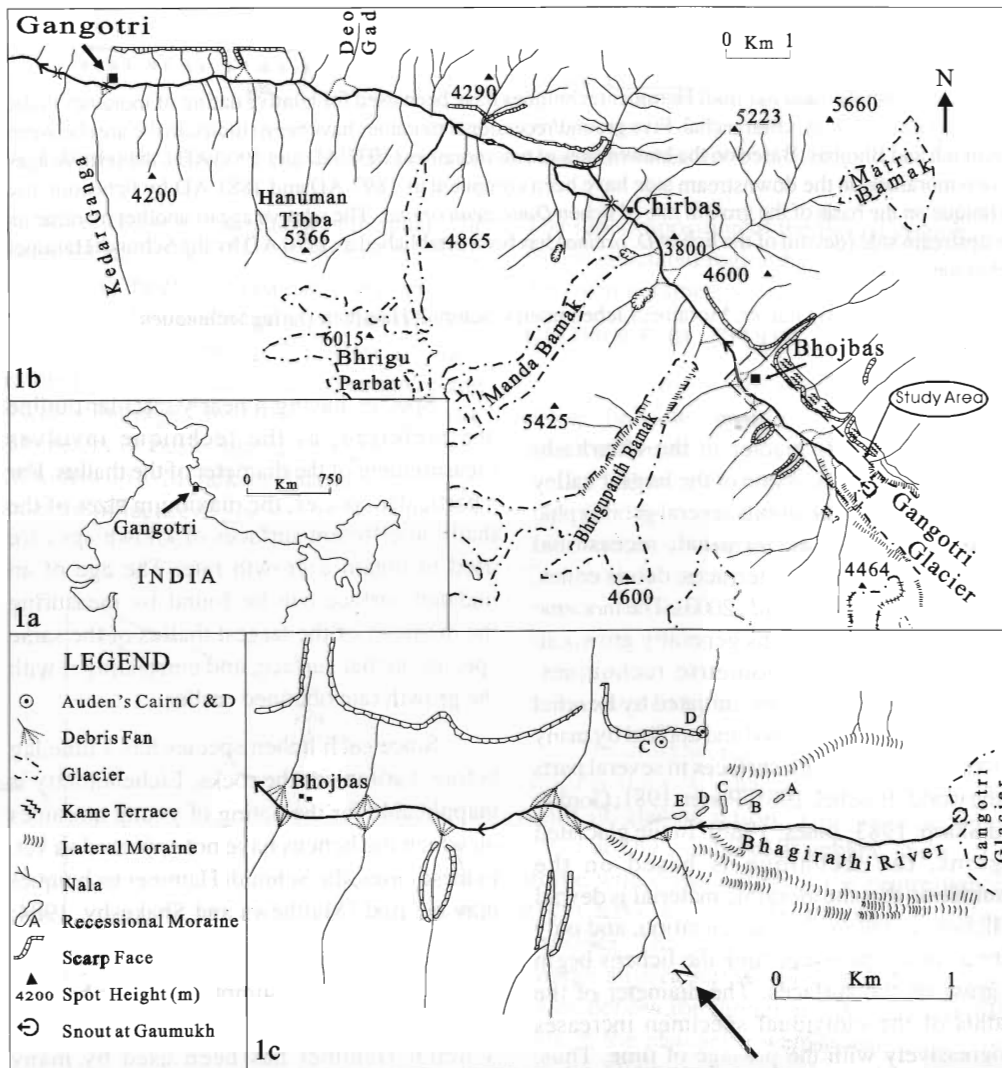

Fig. 1. a Location of Gangotri glacier in India; b: Geomorphological map of the area between Gaumukh and Gangotri; c: Location of the moraines A, B, C, D, and E in the study area.

Table 1: Diameter of the largest thallus of lichen *Dimelaena oreina* in the moraines A, B, C, D and E (Data collected in 2002 AD).

Moraine	Coordinates	Elevation a.s.l.	Diameter of largest thallus of lichen *Dimelaena oreina*
A	79° 4.35'E: 30° 56.12'N	3958 m	Absent
B	79° 4.29'E: 30° 56.19'N	3972 m	24 mm
C	79° 4.16'E: 30° 56.21'N	3954 m	35 mm
D	79° 4.08'E: 30° 56.25'N	3946 m	36 mm
E	79° 4.03'E: 30° 56.29'N	3942 m	41 mm

moraines (moraines A, B, C, D and E, see Table 1, fig. 1c) selected for the present study in the Gangotri glacier valley between Gaumukh and Bhojbas. The moraine B forms a prominent ridge and can easily be identified in the field (fig. 2). The dates of moraines B and C are already established as 1935 AD and 1900 AD respectively (Srivastava *et al.*, 2001).

The area shows the presence of several species of lichens, of which four species, viz. *Rhizocarpon sublucidum, Xanthoria elegans, Dimelaena oreina* and *Umbilicaria indica*

Fig. 2. Photograph of Moraine 'B' forming a ridge in the foreground, with a man on top of the ridge for scale (within red circle), and Left Lateral Moraines in the background.

have been found suitable for lichenometric studies. In the present work, the lichenometric studies are based on the growth rate of the lichen *Dimelaena oreina*.

The lichen *Dimelaena oreina* has a crustose-effigurate thallus (i.e. centrally crustose and marginally lobate), pale greenish-yellow, orbicular in outline, with radiating lobules and black apothecia (fig. 3). The diameters of the largest thalli of the lichen *Dimelaena oreina* growing on the boulders in the moraines A, B, C, D and E have been measured and the maximum diameter of the thallus for each moraine is given in Table - 1. The moraine A is devoid of the species *Dimelaena oreina,* as the lichen has not colonized these rocks as yet. The largest diameters of the thalli of *Dimelaena oreina* for moraines B and C are plotted against the known ages of the moraines, i.e. 1935 AD and 1900 AD respectively (fig. 4). On extrapolation of the graph, the ages of moraines D and E, which are downstream of the moraines B and C, are calculated as 1897 AD and 1881 AD respectively on the basis of lichenometry.

A Schmidt Hammer (Type - L) has been used to determine the rebound or R-values for relative strength of the rock material constituting the boulders in the different moraines of the area. Precautions were taken to minimise the sources of error while operating the instrument. Since measurements with different instruments may vary, only one instrument was used throughout the study, and the data has always been generated with the instrument being held perpendicular to the rock surface. Since lithology has an important control on the degree of weathering, the study was
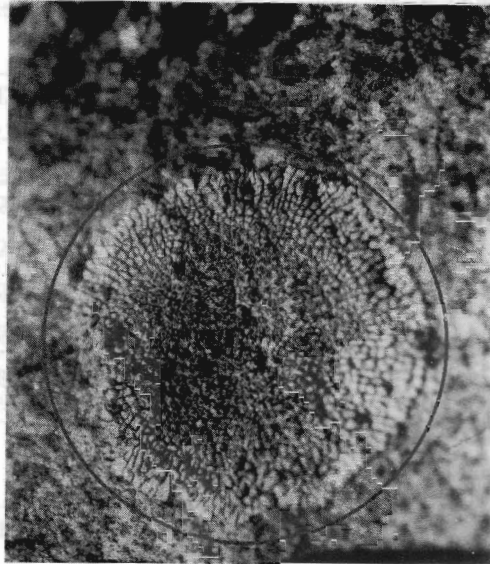

Fig. 3. Photograph of lichen species *Dimelaena oreina.*

restricted to gneissic boulders, which form a dominant lithology of the crystalline rocks of the area (= Central Crystalline Zone).

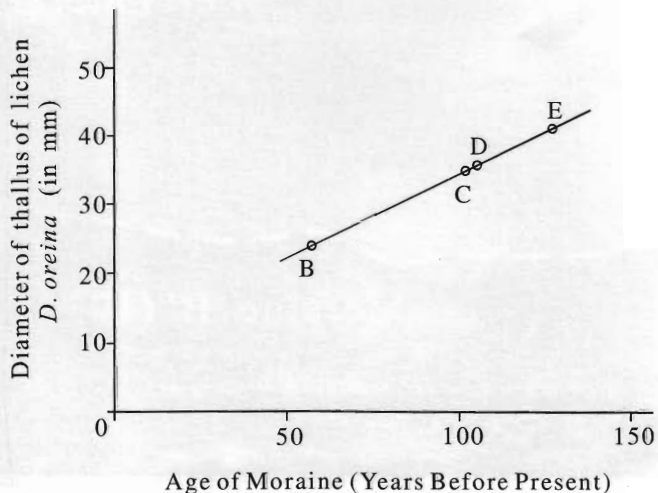The Schmidt Hammer R- values have been recorded for ten boulders on each of the five

Fig. 4. Graph showing diameter of the largest thallus of lichen *Dimelaena oreina* versus age of the moraine.

moraines (A, B, C, D, and E), with five blows per boulder, and the mean of these five blows is presented for the ten boulders of each moraine in Table - 2. The mean R- values so obtained for each moraine are plotted against the known ages of the moraines B and C, and the lichenometric dates for moraines D and E (fig. 5). The date for the moraine A, which is still devoid of the lichen *Dimelaena oreina,* is interpreted from the graph as 1970 AD, on the basis of the mean R-value obtained for the boulders of moraine A.

Fig. 5. Graph showing Schmidt Hammer R-value versus age of moraine.

CONCLUSIONS

The present study indicates that the lichenometric dating technique shows a negative correlation with respect to the Schmidt Hammer technique since the size of the lichen thallus gradually increases with time as the lich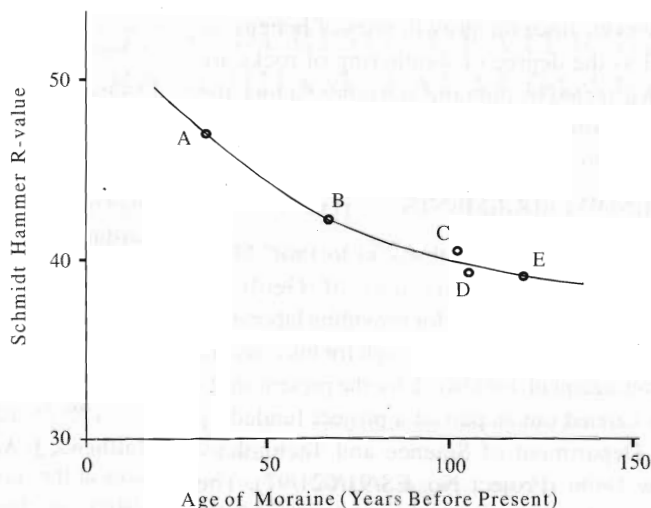en grows, whereas the Schmidt Hammer R-values decreases with time because the intensity of rock weathering increases with time. Both the techniques are extremely useful especially where other dating techniques cannot be successfully employed. Further, the Schmidt Hammer technique may be used to date younger morainic materials on which the lichens have not made their appearance as yet.

Table 2:   Schmidt Hammer R- values for the boulders in the moraines A, B, C, D and E (mean of five blows per boulder).

Boulder No.	Moraine A	Moraine B	Moraine C	Moraine D	Moraine E
1	38.8	39.0	43.2	28.8	35.8
2	48.4	43.0	44.2	48.6	37.0
3	47.2	45.0	46.6	41.2	39.8
4	49.6	36.6	42.8	44.0	33.6
5	46.0	41.6	44.0	39.4	41.6
6	53.0	42.4	30.4	35.6	39.4
7	49.2	45.2	37.6	39.4	37.6
8	48.2	50.8	39.6	48.0	43.8
9	41.6	34.4	37.8	42.2	42.2
10	48.2	46.4	40.6	29.0	44.0
Mean R-values	47.0	42.4	40.7	39.6	39.5

However, since the growth rates of lichens, as well as the degree of weathering of rocks are both affected by climatic and other factors, the correlation data must be generated for each locality to match the studies.

REFERENCES

Auden, J.B. 1937. The Snout of Gangotri glacier, Tehri Garhwal. *Rec. Geol. Surv. India*, **72** : 135-140.

Bali, R., Awasthi, D.D. and Tewari, N. K. 2003. Neotectonic Control on the Geomorphic Evolution of the Gangotri Glacier Valley, Garhwal Himalaya. *Gondwana Research*, **6** : 829-838.

Beschel, R. E. 1961. Dating rock surfaces by lichen growth and its application to Glaciology and Physiography (Lichenometry). *In*: Raasch, G.O. (Ed.), *Geology of the Arctic*. **2** : 1044-62. University of Toronto press, Toronto.

Evans, D. J. A., Archer, S. and Wilson, D. J. H. 1999. A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers. *Quaternary Science Reviews*, **18** : 13-41.

Gordon, J. E. and Sharp, M. 1983. Lichenometry in dating recent glacial landforms and deposits, southeast Iceland. *Boreas*, **12** : p. 191-200.

Innes, John L. 1986. Dating Exposed Surfaces in the Arctic by Lichenometry: The Problem of Thallus Circularity and its Effect on Measurement Errors. *Arctic*, **39**(3) : pp. 253-259.

Matthews, J. A. and Shakesby, R. A. 1984. The status of the 'Little Ice Age' in southern Norway: relative-age dating of Neoglacial moraines with Schmidt hammer and lichenometry. *Boreas*, **13** : 333-346.

Orombelli, G. and Porter, S. C. 1983. Lichen growth curves for the southern flank of the Mont Blanc Massif, western Italian Alps. *Arctic and Alpine Research*, **15**(2) : 193-200.

Porter, S. C. 1981. Lichenometric studies in the Cascade range of Washington: Establishment of *Rhizocarpon geographicum* growth curves at Mount Rainier. *Arctic and Alpine Research*, **13**(1) : 11-23.

Srivastava, D., Bhattacharya, D. N., Shukla, S. P. and Kaul, M. K. 2001. Lichenometry studies on Himalayan glacier. *Geol. Surv. India Spl. Pub.* **53** : 151-155.