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Five-Year Growth of Rock Lichens in a Low-Arctic Mountain Environment, Northern Labrador
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Wachstum von Fels-Flechten in subarktischem Berg-Milieu, nördliches Labrador, über einen Zeitraum von fünf Jahren

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Résumé de l'article

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FIVE-YEAR GROWTH OF ROCK LICHENS IN A LOW-ARCTIC MOUNTAIN ENVIRONMENT, NORTHERN LABRADOR

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ABSTRACT In 1978, three lichen growth stations were established for *Rhizocarpon* section *Rhizocarpon* species and one for *Alectoria miniscula* in the Cirque Mountain area of the Torngat mountains. Five years later, in 1983, the lichens were remeasured. The five-year growth represented by the change in the theoretical diameter is very variable, between 0.10 and 0.54 mm per year. *These rates are larger than expected and* exceed rates previously determined for an eastern Arctic area, the Northern Cumberland Peninsula of Baffin Island, by more than 3 to more than 20 times. Similar rates are known for 'great period' growth outside Arctic regions. If the growth rates represent long-term growth, the ages of recessional moraines in the Torngat Mountains should be recalculated. Moraines formerly described as Late Wisconsin to mid-Holocene may be of Neoglacial age. Variability of growth rates from one individual to another precludes using these data for constructing growth curves which may be used, even locally, in lichenometric dating.

RÉSUMÉ *La croissance de lichens saxicoles sur une période de cinq ans en milieu montagneux subarctique, nord du Labrador.* En 1978, on a établi quatre sites de croissance du lichen dans la région du mont du Cirque dans les monts Torngat: trois sites des espèces *Rhizocarpon* de la section *Rhizocarpon* et un site de *Alectoria miniscula*. Cinq ans plus tard, en 1983, on a mesuré de nouveau *les lichens pour constater que le diamètre* moyen, qui témoigne de la croissance, a crû de manière très variable, soit de 0,10 à 0,54 mm par année. Ces taux de croissance sont plus élevés que prévu puisqu'ils dépassent de 3 à 20 fois les taux déjà mesurés dans le nord de la péninsule de Cumberland, île de Baffin. De tels taux de croissance du lichen s'apparentent davantage à ceux que l'on a observé dans les régions non arctiques au cours de sa période dite de grande croissance. Si ces taux s'appliquent à de longues périodes, il faudrait réévaluer la date de dépôt des moraines de récession dans les monts Torngat. Les moraines, que l'on croit dater de la période s'étendant du Wisconsinien supérieur à l'Holocène moyen, pourraient en fait dater du néoglaciaire. Toutefois, les variations observées entre les taux de croissance ne permettent pas d'utiliser ces données, même à l'échelle locale, pour tracer des courbes de croissance qui serviraient à établir des datations lichénométriques.

ZUSAMMENFASSUNG *Wachstum von Fels-Flechten in subarktischem Berg-Milieu, nördliches Labrador, über einen Zeitraum von fünf Jahren.* 1978 wurden im Cirque-Mountain-Gebiet der Torngat mountains vier Stationen zur Beobachtung des Flechten-Wachstums eingerichtet: drei Stationen für *Rhizocarpon*-Arten der Sektion *Rhizocarpon* und eine Station für *Alectoria miniscula*. Fünf *Jahre später, 1983, wurden die Flechten* wieder gemessen. Der Fünfjahreswuchs, der sich im Wechsel des durchschnittlichen Durchmessers ablesen läßt, ist sehr unterschiedlich, zwischen 0.10 und 0.54 mm pro Jahr. Diese Wachstumsraten sind größer als erwartet und gehen über die zuvor für ein östliches arktisches Gebiet, die Nord-Cumberland Halbinsel der Insel Baffin, bestimmten Raten mehr als dreifach bis zu mehr als zwanzigfach hinaus. Ähnliche Wachstumsraten sind für die 'große Periode' des Flechten-Wachstums außerhalb der arktischen Gebiete bekannt. Wenn die Wachstumsraten Langzeit-Wachstum repräsentieren, müßte das Alter der Rückzugs-Moränen in den Torngat-Bergen neu berechnet werden. Moränen, die zuvor dem späten Wisconsin bis mittleren Holozän zugeschrieben wurden, könnten aus der Neoglazialzeit stammen. Die Variationen der Wachstumsraten von einer Person zur anderen schließen eine Nutzung dieser Daten zum Aufbau von Wachstumskurven aus, welche, selbst lokal, zur Datierung auf der Basis der Flechten benutzt werden könnten.

INTRODUCTION

In the last 30 years, lichenometry has been widely used as a technique for relative dating of late Holocene events such as glacier recession (INNES, 1985a). Lichens are among the first plant forms to colonise newly-exposed rock surfaces and, since subsequent growth results in a relatively steady increase in the thallus size of individual lichens, lichen size is thought to be directly proportional to age. This relative dating technique may provide some absolute dates for geological events if the growth rate of the particular species of lichen is known for the area studied. Growth rates are very sensitive to climate and thus may vary significantly from place to place. They may be obtained indirectly by measuring sizes on substrates of known age, or directly by precise measurement of the same lichen thallus over time (LOCKE *et al.*, 1979). In this paper the latter approach is taken in an attempt to redate glacier recession in an area of northern Labrador.

In early August 1978 four lichen growth stations were established and photographed at an altitude of 460 m and *ca.* 3 km northwest of Cirque Mountain (1570 m) in the Torngat Mountains of northern Labrador (McCOY, 1983) (Fig. 1). Station 1 had a single *Rhizocarpon*[1] with a mean diameter of 50.6 mm; Station 2 had three *Rhizocarpon* with mean diameters of 35.1, 27.5 and 17.8 mm; Station 3 had three *Rhizocarpon* with mean diameters of 24.8, 24.9 and 17.5 mm; Station 4 had a single *Alectoria miniscula* with a mean diameter of 68.6 mm.

The stations are all located less than 100 m from the northeast corner of a distinctive lake (Fig. 1), in an area where McCOY reconstructed a local chronology of moraine abandonment based on minimum diameters of the largest lichens and an approximate growth rate of .03 mm per year. This rate was developed by MILLER (1973) for northern Cumberland Peninsula, Baffin Island, but considered to be suitable as a preliminary growth rate for northern Labrador. The age of the lichen cover in the vicinity of the Stations was estimated to be >4000 years, based on the size of the largest lichens and Miller's growth rates. However, the individual lichens in the stations were smaller and were thought to vary from ca. 580 years to 1650 years in 1978, based on Miller's rates of growth. The objective of this paper is to apply the direct method for determining lichen growth rates to confirm or reject the use of Miller's rates in northern Labrador.

METHODS

McCoy's lichen growth stations were relocated and the individual lichens re-photographed with a 35 mm camera in late July 1983. As in 1978, care was taken to centre the lichens in the frame to minimize lens-edge distortion. A 1 cm^2 or 4 cm^2 scale was included in the same position in the photograph as in 1978. Negatives were produced and, using an enlarger to ensure accuracy, prints for both years were produced at identical scales. The thallus outlines, or prothalli, were traced and the 1978 outlines superimposed over the 1983 outlines. Clear differences between 1978 and 1983 lichen sizes are apparent in all cases (Fig. 2). The differences are concentrated neither around the lobes, nor in embayments on the prothalli, but are general to the whole outlines. Only the lichens at station 3 and 4 had parts of their prothalli which appeared unchanged between 1978 and 1983. In all these cases, the lengths of unchanged prothalli are less than one-third the perimeter length of the lichens concerned.

Lichen size has been measured in several different ways. To indicate the relative age of a substrate, it is usual to identify the largest thallus and to measure its diameter. Maximum, minimum, mean or modal diameters have been suggested (see LOCKE *et al.*, 1979 and INNES, 1985a for full discussion). However, when lichen stations are established for construction of lichen growth curves, more precise measures of size are used. HOOKER and BROWNE (1977) developed a photogrammetric method, carefully making corrections for distortion, but determining size as the average of up to 16 lobe radii for an individual thallus. This is similar to the standard method described by LOCKE *et al.* (1979) which was used in this study for its simplicity. Individual lichen areas were measured using a precision co-ordinate digitizer, and mean theoretical diameters were calculated. Either change in theoretical diameter or change in areas can be used as measures of growth. Diameter is the more usual since results are directly applicable to the diameter measure of size used in lichenometric dating (INNES, 1985a).

RESULTS

Table I is a summary of the lichen growth data. Individual lichen thallus diameters increased between 0.10 and 0.58 mm per year for the period 1978-1983, with a mean increase for seven *Rhizocarpon* of 0.34 $\pm$.19 mm per year. The single *Alectoria miniscula* had a growth rate of 0.12 mm per year. Percentage increases in size ranged from 3.83% to 23.69% for *Rhizacarpon*, and 1.68% for *Alectoria miniscula*. They did not clearly vary with thallus diameter, although they showed some weak inverse relationship (Fig. 3d). In addition, no clear relationship between absolute increase in diameter and lichen thallus area in 1978 could be distinguished (Fig. 3c). An inverse relationship between any expression of lichen growth and initial (1978) size was expected since the 'great period' of growth of a lichen usually occurs in the first 50 to 500 years (LAWREY and HALE 1977). Also, the larger lichens were thought, by their size, to be beyond the 'great period', and in the 'maturation period' of linear growth. ARMSTRONG (1983) maintains that growth curves for *Rhizocarpon geographicum* differ from asymptotic curves of other lichens and diameter increase could approach zero at large diameters.

1. Following the suggestion of INNES (1985b), the lichens are identified by their section (*Rhizocarpon*) and series (*Rhizocarpon*) name since no laboratory identification is possible to determine if all are *Rhizocarpon geographicum* as reported in McCOY 1983. INNES (1985b) maintains that many lichenometric studies are of lichens which have been identified in the field only and when this is the case the term *Rhizocarpon geographicum* should not be used.

COMPARISONS AND DISCUSSION

The measured rates of growth are much higher than those for the northern Cumberland Peninsula used by McCOY (1983). The maximum rate of *Rhizocarpon* growth measured (0.58 mm per year) is closer to the 'great period' growth rates reported for Alpine Europe (BESCHEL, 1957), the Pacific Northwest (MILLER, 1969) and South Island, New Zealand (BURROWS and LUCAS, 1967) than those derived for most of Arctic Canada, including Baffin Island. Higher growth rates are known from Tunsbergdal in South Norway (MOTTERSHEAD and WHITE, 1972) and Wales (ARMSTRONG, 1983), but in both these cases the maximum rates of 0.9 mm per year were measured for small lichens approximately 20 mm in diameter. In Norway the rate decreased to 0.34 mm per year when the lichens reached a diameter of 65 mm. MATTHEWS (1974) working in Jotunheimen, Norway, reports a rate of 0.75 mm per year at a size of 20 mm, decreasing to 0.40 mm per year for diameters approaching 100 mm.

In contrast to these, MILLER and ANDREWS (1972) report 0.15 mm per year until the lichen is *ca.* 15 mm, subsequently decreasing to 0.03 mm per year on northern Cumberland Peninsula, Baffin Island. In Labrador, lichen growth could be similar to that described by BESCHEL (1961) for West Greenland where oceanic climates of the outer coast were thought to have higher lichen growth rates than the dry continental climates of the inner fiords.

LAWREY and HALE (1977) identify the four growth phases of lichens as: a) juvenile phase, with a low rate of growth; b) 'great period', with a maximum rate lasting 50 to 500 years; c) maturation period of linear growth for >1000 years, to a maximum size for reliable dating (suggested as 75 mm by OROMBELLI and PORTER, 1983); d) senescence period of decreased growth, no growth (ARMSTRONG, 1983) or disintegration.

For *Rhizocarpon geographicum*, the passage from 'great period' to maturation is thought to occur when the thallus has

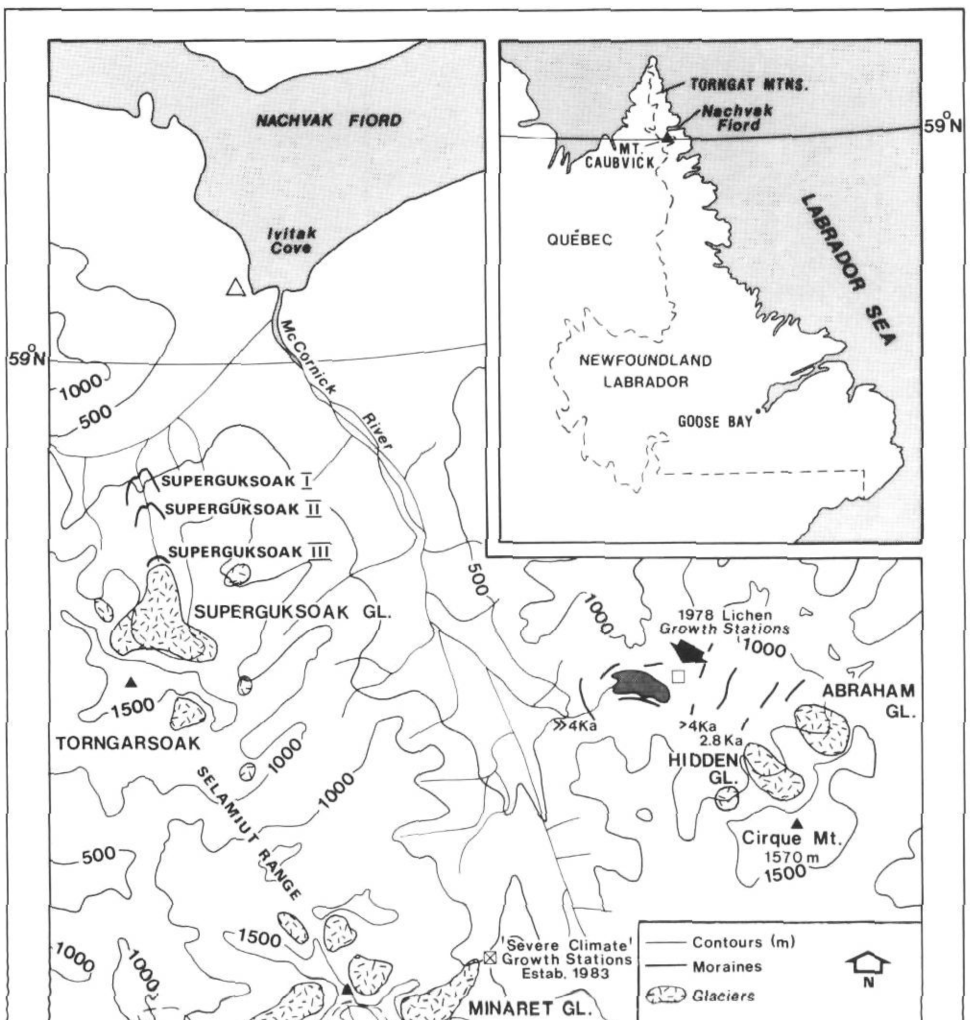

FIGURE 1. Location of lichen growth stations in northern Labrador and the moraines dated using lichenometry.

Localisation des sites de croissance du lichen et des moraines datées par lichénométrie.

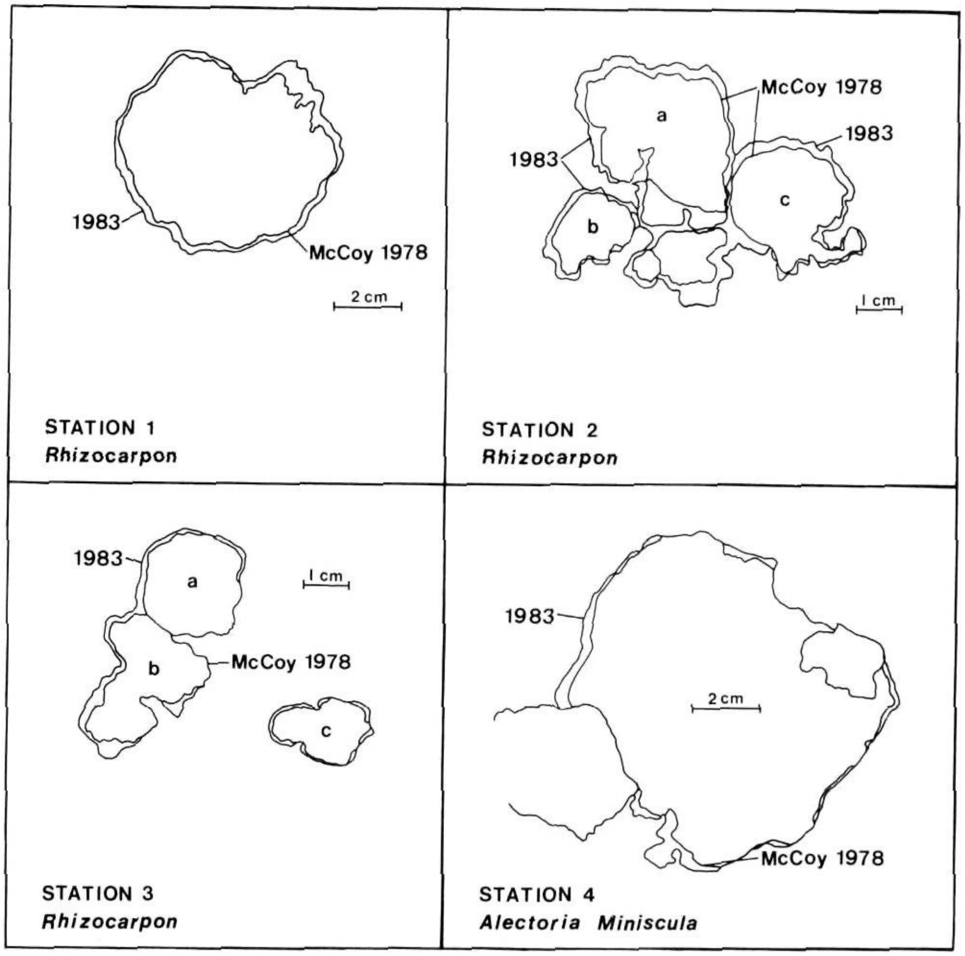

FIGURE 2. Outlines of lichens in 1978 and 1983 at four growth stations.

Contours des lichens observés en 1978 et en 1983 dans les quatre sites.

TABLE I

Lichen Growth Data

Station	lichen	Area (cm^2) 1978	Area (cm^2) 1983	% growth	Diameter (mm) 1978	Diameter (mm) 1983	mm growth	Growth (mm per year)
1	*Rhizo.*	20.10	22.32	11.04	50.6	53.3	2.7	0.54
2a	*Rhizo.*	9.67	10.04	3.83	35.1	35.8	0.7	0.14
2b	*Rhizo.*	2.49	3.08	23.69	17.8	19.8	2.0	0.40
2c	*Rhizo.*	5.95	7.27	22.18	27.5	30.4	2.9	0.58
3a	*Rhizo.*	4.82	5.03	4.36	24.8	25.3	0.5	0.10
3b	*Rhizo.*	4.87	5.65	16.02	24.9	26.8	1.9	0.38
3c	*Rhizo.*	2.41	2.73	13.28	17.5	18.6	1.1	0.22
4	*Al. min.*	36.95	37.57	1.68	68.6	69.2	0.6	0.12

a diameter of 35 to 40 mm (PROCTOR, 1983). Only two of the Torngat stations had lichens greater than this size in 1978, yet one of those (Station 1) had the second highest growth rate measured (Table I).

The growth rates of the Torngat lichens appear to be typical of the 'great period'. This suggests that the lichens are younger than the 580 to 1650 years estimated from Miller's growth rates. 'Great periods' are believed to last from a few decades to about 500 years, and those with growth rates of approximately 0.46 mm per year are usually associated with great period 'durations' of 100 to 300 years (WEBBER and ANDREWS, 1973).

Using the measured growth rates specific to the individual lichens, both the smallest lichen (17.5 mm) and the largest (50.6 mm) may have been approximately 90 years old, and the oldest lichen only 250 years old in 1978. The mean growth rate of 0.34 mm per year would suggest an age of 150 years old for the largest lichen.

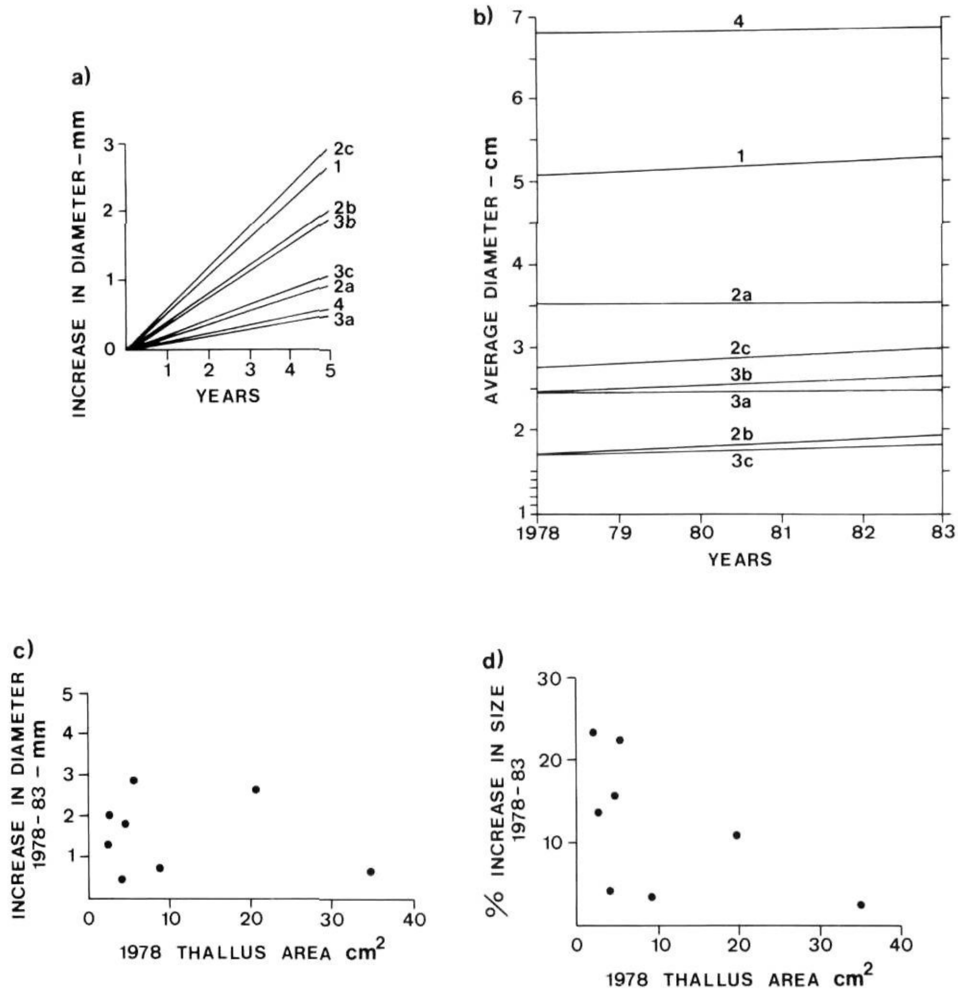

FIGURE 3. Graphic representations of statistics on lichen growth, 1978—1983: a) increase in diameter in five years; b) average diameters in 1978 and 1983; c) absolute increase in diameters as a function of lichen size (thallus area); d) percentage increase as a function of size.

Représentations graphiques des données statistiques recueillies sur la croissance des lichens de 1978 à 1983: a) accroissement du diamètre en cinq ans; b) diamètres moyens en 1978 et en 1983; c) accroissement absolu des diamètres en fonction de la taille des lichens (thalles); d) accroissement en pourcentages en fonction de la taille.

REDATING GLACIER RECESSION

If the measured rates of lichen growth are accepted as representing growth over a longer term than five years, it is reasonable to recalculate the dates of abandonment of moraines in the Torngat Mountains. Table II outlines the differences between the ages calculated by McCOY (1983) for the Cirque Mountain area, from Miller's growth rates, and the ages calculated using the maximum, mean and minimum growth rates obtained in 1983. For further comparison, soils dating is included for the four oldest events using values of depth to the base of the B-horizon published by McCOY (1983), but not previously included in his chronology.

Scrutiny of air photographs taken in 1949 (LAB 48) and 1950 (LAB 92), approximately 30 years before the lichen stations were established, revealed that the ice margin at Abraham Glacier (Fig. 1) had not fluctuated by more than 20 m. In 1949, ice covered the area formerly dated <150 years since deglaciation (McCOY, 1983), suggesting the recalculated mean age of 41 years is close to correct. This would also suggest the maximum growth rate in Table II is not likely correct.

Table III outlines the differences between the age of moraines in the Superguksoak Valley area (Fig. 1) according to *Miller's growth rate and soils evidence* (EVANS and ROGERSON, 1986), and the recalculated substrate ages based on the Cirque Mountain lichen growth rates.

The recalculations in Tables II and III challenge several earlier conclusions made on the deglaciation of the Torngat Mountains. The large moraine loops located within 5 km of the terminus of Abraham, Hidden and Superguksoak Glaciers would be of Neoglacial rather than Late Wisconsinan to Early Holocene age, based on the local rates of lichen growth. All the moraines in both areas could have formed within the last 1300 years. In both areas soils dating suggests earlier dates for the older events than does lichenometry. However, the rate of soil development (approximately 1.0 cm per thousand years) used both by McCOY (1983) and by EVANS and ROGERSON (1986), is taken from Baffin Island (EVANS and CAMERON, 1979), and from a preliminary curve of soil development, based on only two dates, in the Kangalaksiorvik area of Labrador, only 50 km to the north of the Cirque Mountain area (CLARK, 1984). Soil development, like lichen growth,

TABLE II

A comparison between ages calculated from maximum thallus sizes and Miller's growth rates (McCOY, 1983), and ages calculated using the same sizes but maximum, mean and minimum growth rates measured from 1978-1983

Moraine abandoned, (McCOY, 1983) years before 1978	Maximum *Rhizo.* diam. (mm)	Recalculated age from 1978-1983 rates max. 0.58	mean 0.34	min. 0.10	Soil age from data in McCOY (1983)**
<150	14	24	41	140	
400	25	43	74	250	
550-750	34	59	100	340	
950	41	71	121	410	
=/>1850	67	116	197	670	
>1850	64*				
=/>2800	92	159	271	920	1500-2000
>2800	78*				1200*
=/>4000	122	210	359	1220	800-2000
>>4000	84*				1100-2500

* Not indicative of true age as up-valley moraine has larger lichens or deeper soils.
** McCOY (1983) Table II, depth to the base of the B horizon (cm) times 100 (rate from EVANS and CAMERON, 1979).

TABLE III

Recalculation of the ages of glacial phases in the Superguksoak Valley, based on 1978-1983 lichen growth data.

Phase and possible age in years BP*		Max. *Rhizo.* diam. mm	Recalculated age using 1978-1983 rates max.	mean	min.	Soil age in years BP*
Superguksoak III	1500	20	34	58	200	no soil/proximal side
		50	86	147	500	no soil/moraine crest
Superguksoak II	3-5000	90	155	265	900	5000
Superguksoak I	5-12000	100	172	294	1000	5000

* EVANS and ROGERSON, 1986.

TABLE IV

Speculative rates of soil development based on 1978-1983 rates of lichen growth and B horizon depths obtained from closely-related soils

McCOY (1983) moraine abandonment age (years BP)	Mean age from Table II (years BP)	B horizon depth (cm)	Rate of soil development (cm per 1000 years)
=/>2800	271	15-20	55-74
=/>4000	359	8-20	22-56
EVANS & ROGERSON phases, Table III age			
Superguksoak III	58-147	0	
Superguksoak II	265	5	19
Superguksoak I	294	5	17

may be more rapid in northern Labrador than it is on Baffin Island, which could mean that the soils-based ages are too great.

These data permit speculation on the rates of soil development required to provide a perfect agreement between lichenometry and soils dating in the Torngat. Table IV suggests that the rates would be 22 to 74 cm per thousand years for the Cirque Mountain area and 18 cm per thousand years for the Superguksoak area. These are very high rates of soil development, possibly a whole order of magnitude higher than any other Arctic locality, and may be unrealistic. Yet both lichen growth and soil development are functions of climate. The Torngat is an area of relatively long growing season, warm temperatures and high precipitation compared with most Arctic localities, and these are all factors likely to increase both lichen growth and soil development.

Perhaps the most significant result from this study is that large variations in short-term growth rates occur within a small area. These variations suggest that short-term measurements of lichen growth, with a time interval of five years, may be insufficient for constructing precise local growth curves, despite the claim that three growing seasons is a sufficient interval to average out anomalous summers (LOCKE *et al.*, 1979). Nevertheless, growth rates determined by MILLER (1973) on the Cumberland Peninsula, Baffin Island, cannot be used for northern Labrador in view of the magnitude of growth from all direct measurements made in this study.

In 1983, further lichen growth stations were marked and photographed at a 'severe' climate site, at 900 m asl, near the terminus of Minaret Glacier (Fig. 1). Future remeasurement at these and the 1978 growth sites, may settle whether growth rates are also high and variable in a severe topoclimate, and whether growth remains highly variable over a longer time span. These are important questions in lichenometry where small differences in lichen sizes are often inferred to represent significant time intervals.

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