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Article abstract

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HOLOCENE GLACIER FLUCTUATIONS IN THE TORNGAT MOUNTAINS, NORTHERN LABRADOR

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ABSTRACT Lichen measurements and other relative-age data were collected from deposits of several cirque glaciers in the Torngat Mountains of northern Labrador. Lichen growth stations were established, but no lichen-growth curve has yet been determined for the local area. However, moraines can be correlated between valleys on the basis of the largest diameter thallus of *Rhizocarpon geographicum sensu lato* combined with other relative-age data. These data suggest several discrete periods of Holocene glacier recession. If the *R. geographicum s. l.* growth curve established for the northern Cumberland Peninsula of Baffin Island (MILLER, 1975) is valid for similar environments in the Torngat Mountains, then glacier recession occurred c. $<$150, 400, 550-750, 950, $\geq$1850, $>$1850, $\geq$2800, $>$2800, $\geq$4000, and $>>$4000 yr BP. The latest three periods of glacier recession may correlate with periods of glacier recession on the Cumberland Peninsula of Baffin Island.

RÉSUMÉ *Fluctuations glaciaires holocènes dans les monts Torngat, nord du Labrador.* On a effectué des mesures de lichens et recueilli des données sur l'âge relatif des dépôts de plusieurs cirques glaciaires des monts Torngat, au nord du Labrador. On y a déterminé des aires témoins de croissance des lichens, sans avoir pu encore dresser de courbe pour la région. Toutefois, on a pu établir des correspondances entre les moraines de vallées à partir des plus grands diamètres de thalles de *Rhizocarpon geographicum sensu lato* en combinaison avec d'autres données sur les âges relatifs. Ces données laissent croire qu'il y a eu plusieurs périodes discontinues de récession glaciaire au cours de l'Holocène. Si la courbe de croissance de *R. geographicum s. l.* déjà dressée pour le nord de la péninsule de Cumberland, île de Baffin, s'applique à des milieux similaires dans les monts Torngat, on peut avancer qu'il y a eu des périodes de récession glaciaire vers $<$150, 400, 550-750, 950, $\geq$1850, $>$1850, $\geq$2800, $>$2800, $\geq$4000 et $>>$4000 ans BP. Les trois dernières périodes pourraient correspondre à celles qu'a connues la péninsule de Cumberland, île de Baffin.

INTRODUCTION

Deposits of several Holocene cirque and valley glaciers in two areas of the Torngat Mountains were studied in the field to determine their relative and numerical ages. The more continental of the two study areas includes six moraines from an area about 5 km south of the northeastern end of Upper Komaktorvik Lake, and approximately 45 km inland from the outer coast (Fig. 1). The more maritime area includes sixteen moraines in a cirque complex in the McCornick River drainage south of Nachvak Fjord. This second study area is only about 25 km inland from the outer coast.

Previous work in the area has not included any systematic study of the chronology of Holocene glacier fluctuations. The glacial geomorphology of the region was studied by IVES (1957, 1958, 1978). LØKEN (1962) described cirque moraines in parts of the northern Torngat Mountains, but he reported no attempt to date the Holocene moraines.

Parameters of relative age measured on each moraine were: the diameter of the largest individual lichen thallus of the species *Rhizocarpon geographicum sensu lato*, the percentage lichen cover, and the percentage vegetation cover. Soil pits were dug on many of the moraines. A description of the soil profile was noted and samples were taken for laboratory analyses. No suitable material was found for radiometric dating of any of the moraines.

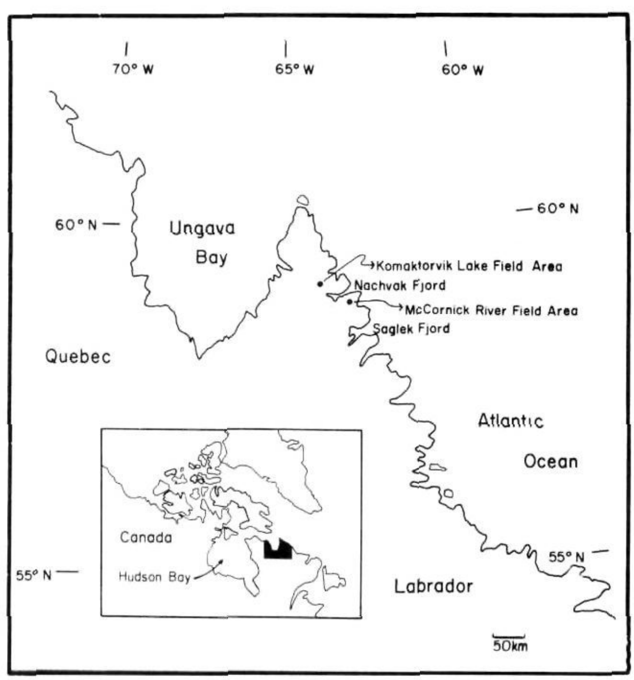

FIGURE 1. Location map showing Komaktorvik and McCornick field areas.

Carte de localisation des secteurs étudiées au lac Komaktorvik et à la rivière McCornick.

LICHENOMETRY

The largest lichen thallus of a given species on a moraine is indicative of the time of colonization by lichens on an exposed rock surface. It may also be indicative of the time of initial glacier recession and moraine stabilization after an advance to or stillstand at the terminal moraine position (MILLER, 1973). In this study, the minimum diameter of the largest *R. geographicum s. l.* thallus found during a twenty-minute search by two people on each moraine was taken as an index of relative age of the substrate.

On each moraine the largest lichen found was not much larger than several others found on the same moraine. This suggests that the largest thallus was not exceptionally large and, following the criterion of DENTON and KARLEN (1977), can be accepted as representing the oldest lichens that colonized the moraine after stabilization. Furthermore, it is unlikely that a more prolonged search of each moraine would have revealed significantly larger *R. geographicum* thalli. This sampling technique is effectively similar to the "selective walk" technique used by MILLER (1973, 1975), whose results will be compared with those presented here. Lichen measurement sites are shown in Figure 2 and the lichen data is presented in Table 1.

Analysis of the lichen data (Table I, Fig. 2 and 3) suggests that moraines with lichens larger than 50 mm in diameter are not always in the expected morphostratigraphic sequence, *i.e.* moraines with smaller maximum lichens sometimes lie downvalley from moraines with larger maximum lichens. For example, the minimum diameter of the largest *R. geographicum s. l.* on the moraine at site 4 is 91 mm, but the minimum diameter of the largest *R. geographicum s. l.* at site 6, downvalley

TABLE I

Characteristics of moraines

Site[a]	Approximate Age (yr. BP)[b]	Maximum diameter (mm) *Rhizocarpon geographicum*	Maximum diameter (mm) *Alectoria miniscula*	Lichen cover (%)	Vegetation cover (%)	Soil characteristics
0,13a, K_1	<50	0	0	<1	0	no horizonation
K_2	<100	8	28	<1	—	—
K_3	<100	10	50	<1	—	—
13b	<150	13	—	5	1-5	no horizonation
1a	<150	14	—	5	1-5	no horizonation
1b	400	25	—	<5	1-5	no horizonation
2	550	29	—	5	5-10	no horizonation, some silt translocation
K_4	625	31	82	<1	—	—
3a	750	34	47	5	<1	only boulders at surface
3	950	41	92	25	5-10	—
K_5	⩾1850	67[c]	104	10-90	—	—
K_6	>1850	64[d]	—	10-90	—	—
4	⩾2800	91[d]	—	50-95	35-50	A/B/Cox with some silt translocation
13c	⩾2800	92[c]	—	30-90	15-20	A/B/C with some silt translocation
6	>2800	78[d]	150	40-80	15-50	A/Cox with considerable silt translocation & considerable organic matter in A horizon
7,8	⩾4000	122[c]	—	40-95	15-50	A/B/Cox
9, 10, 11	>4000	84[d]	—	50-95	30-50	A/B/Cox
12, 21, 24	>>4000	—	—	60-95	60-75	A/B/Cox with much silt & clay translocation; much better developed A & B horizons than younger soils

[a] refer to Figure 2 for locations of numbered sites; sites designated by a K and a subscript refer to those in the Komaktorvik field area and are not shown in Figure 2.

[b] approximate age based on lichen growth curve for *Rhizocarpon geographicum* for Cumberland Peninsula compiled by DAVIS (1980) after MILLER (1973); uncertainty in numerical age is about ± 20% (MILLER, 1973) assuming that the lichen growth rates are similar in northern Labrador and eastern Baffin Island.

[c] the largest lichens at these sites are acircular with indistinct margins and are used to estimate minimum ages only.

[d] minimum diameter of largest lichen at these sites is not indicative of true age of moraine as upvalley moraine has larger lichens.

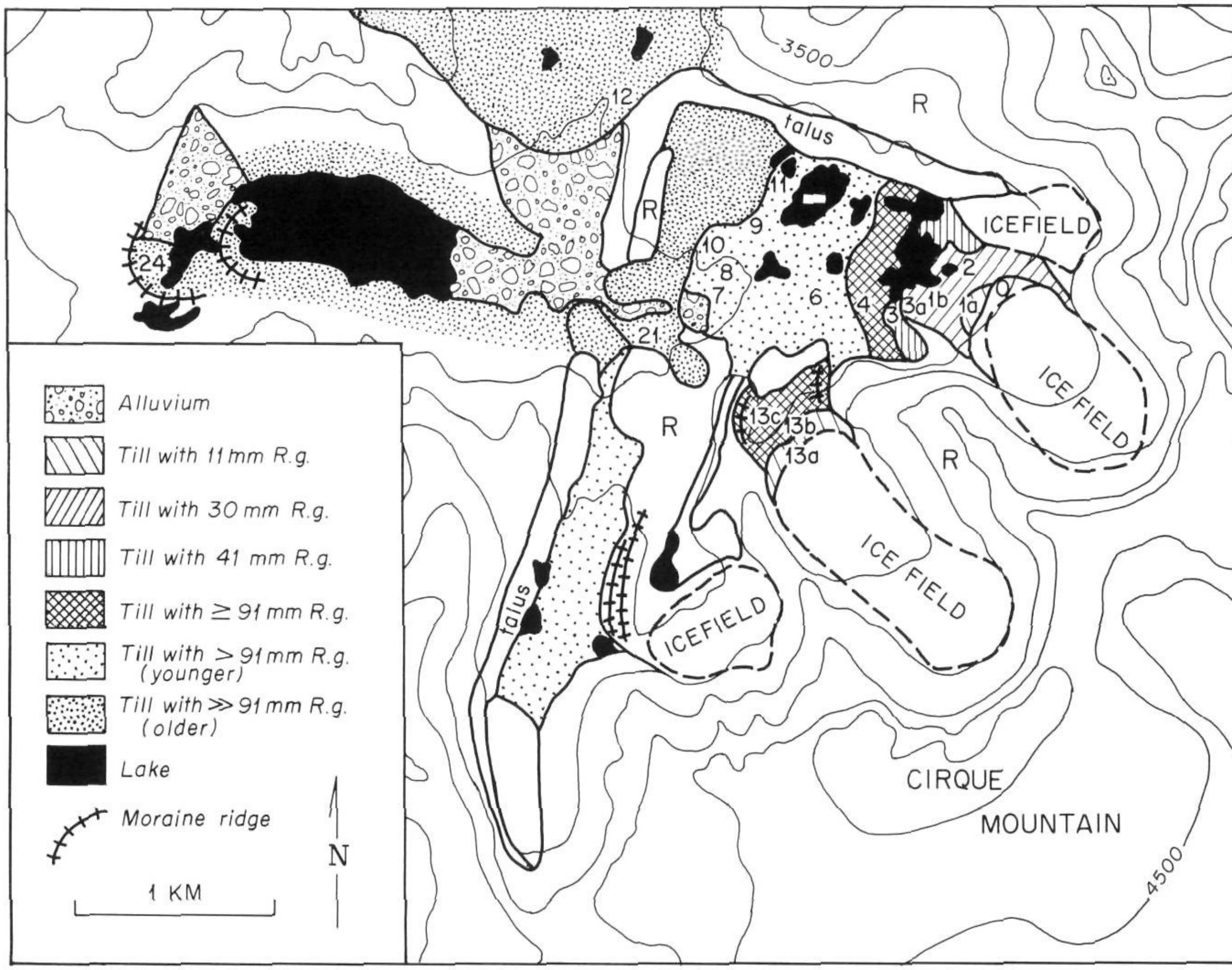

FIGURE 2. Map of late Quaternary glacial deposits of the field area in the McCornick River drainage. Numbers refer to sites listed in tables I and II and are discussed in text.

Carte des dépôts glaciaires du Quaternaire supérieur dans le bassin-versant de la partie à l'étude de la rivière McCormick. Les chiffres se rapportent aux sites énumérés dans les tableaux I et II et commentés dans le texte.

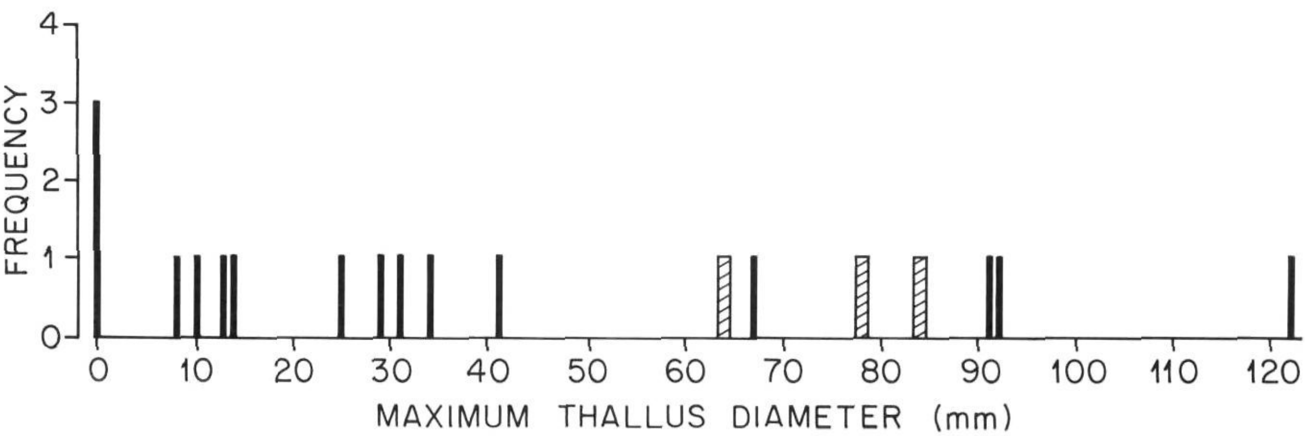

FIGURE 3. Size/frequency diagram of the largest *Rhizocarpon geographicum s.l.* thalli found on all moraines studied. Hachured lines represent moraines with maximum *R. geographicum* thalli smaller than those on moraines lying upvalley (see text for discussion).

Diagramme dimension/fréquences des plus grandes thalles de Rhizocarpon geographicum s.l. *trouvées sur toutes les moraines étudiées. Les hachures représentent les moraines dont les plus grandes thalles de* R. geographicum *sont plus petites que celles qui apparaissent sur les moraines en amont (voir le texte).*

from site 4, is only 78 mm. Possibly the largest lichens were simply not found at site 6. Alternatively, the oldest lichens have not survived intact. *R. geographicum* thalli larger than 50 mm in diameter are usually of irregular form and have indistinct margins, as if they have been eroded. The surface texture of the boulders of these older moraines is less smooth than that of the younger moraines. These facts suggest that, as a consequence of chemical and physical weathering, granular disintegration of boulder surfaces sometimes limits the maximum size that *R. geographicum* may attain. Therefore, in this study *R. geographicum* thalli greater than 50 mm in their shortest diameter are interpreted as providing only minimum numerical ages for their substrates.

Lichen growth stations were established in August, 1978, in the field area south of Nachvak Fjord at an elevation of about 500 m asl. *Rhizocarpon geographicum s. l.* and *Alectoria miniscula* of various sizes were photographed next to a 1 × 1 cm scale. The growth rates of these lichens may be determined only after remeasurement at some future time.

RELATIVE AGE DATA

The relative age data presented in Table 1 support the relative age assignments that are based on the lichen size data and the morphostratigraphy. Both the percentage total lichen cover and the percentage vegetation cover generally increase with the size of the

TABLE II

Soil data for tills in the McCornick River study area

Site (with approx. age in parentheses)	Horizon[1]	Depth	Color (dry)	% by weight of <2 mm fraction: Sand	Silt	Clay	Organic Matter %
1a (<150 yr. BP)	Cn	0-20+	2.5Y 6/2	71.7	21.6	6.7	0.52
2 (550 yr. BP)	Cn	0-20+	2.5Y 6/2	79.8	14.8	5.4	0.53
3a (750 yr. BP)	Cn	0-20+	2.5Y 6/2	69.7	22.3	8.0	0.42
4	A	0-5	10YR 4/3	88.8	8.9	2.3	3.36
(⩾2800 yr. BP)	B	5-15	10YR 4/3	84.8	12.9	2.4	1.52
	Cox	15-20+	2.5Y 6/4	68.1	27.2	4.7	1.00
13c	A	0-3	10YR 3/3	91.7	7.0	1.3	1.58
(⩾2800 yr. BP)	B	3-20+	10YR 4/3	85.2	13.6	1.2	1.29
6	A	0-5	10YR 4/3	65.4	29.4	5.2	3.72
(>2800 yr. BP)	Cox	5-12	2.5Y 6/2	67.8	27.3	4.9	1.13
	Cn	12-20+	2.5Y 6/2	58.6	34.6	6.8	0.70
7	A	0-5	10YR 3/3	97.7	0.6	1.7	1.86
(⩾4000 yr. BP)	B	5-20+	10YR 4/3	92.5	5.0	2.5	1.18
8	A	0-2	10YR 4/3	78.2	19.5	2.4	2.49
(⩾4000 yr. BP)	B	2-8	10YR 5/3	64.9	30.5	4.5	0.96
	Cox	8-20+	2.5Y 6/2	72.1	24.0	3.9	0.86
9	A	0-3	10YR 4/3	83.0	15.2	1.8	3.12
(>4000 yr. BP)	B	3-10	10YR 6/3	72.0	26.7	1.3	0.98
	Cox	10-20+	2.5Y 6/3	73.8	25.4	0.8	0.53
10	A	0-2	10YR 3/3	84.5	12.3	3.2	4.18
(>4000 yr. BP)	B	2-11	10YR 5/3	67.6	29.4	3.0	2.59
	Cox	11-20+	2.5Y 6/2	68.4	29.4	2.2	0.98
11	A	0-3	10YR 5/3	76.7	22.2	1.1	2.06
(>4000 yr. BP)	B	3-15	10YR 5/3	73.1	25.5	1.4	1.67
	Cox	15-20+	2.5Y 6/2	72.1	26.7	1.2	0.92
12	A	0-8	10YR 4/3	71.8	25.0	3.2	4.30
(>>4000 yr. BP)	B	8-17	10YR 6/3	65.2	31.8	3.0	0.76
	Cox	17-20+	2.5Y 6/2	77.6	20.5	1.9	0.48
21	A	0-10	10YR 5/3	75.7	21.1	3.2	2.43
(>>4000 yr. BP)	B	10-25	10YR 6/2	41.0	51.3	7.7	1.49
	Cox	25-30+	2.5Y 6/2	72.2	24.9	2.9	0.75
24	A	0-5	10YR 3/3	88.7	8.2	3.1	4.36
(>>4000 yr. BP)	B	5-25+	10YR 4/3	85.0	13.0	1.9	2.31

[1] B refers to a cambic B horizon based on hue as suggested by BIRKELAND (1974, 1978).

largest *R. geographicum* thallus and the distance down-valley from the present glacier termini.

Soil pits were dug only in the McCornick River drainage field area. Soil development can be seen to progress with the age of the moraines as determined by the lichen data (Tables I and II) and may be used as the basis for the differentiation of some of the moraines that are beyond the range of lichenometry. Soils formed on moraines that have maximum *R. geographicum s. l.* diameters less than 35 mm have incipient or very weak A horizons overlying unoxidized parent material with little or no evidence of silt or clay translocation in the profile. The surface of the next older moraine (site 3) in the McCornick River study area was covered with boulders and was without soil. The soils of the only moraines with maximum *R. geographicum* diameters between 42 and 90 mm, which are in the Komaktorvik field area, were not examined. The moraines at sites 4 and 13c have large maximum *R. geographicum* diameters (91-92 mm) and have soils with better developed A horizons, each overlying a cambic B horizon with good evidence for the downward translocation of silt and some clay. Evidence for translocation of fine particles in similar soils on the Cumberland Peninsula of Baffin Island has been observed by BOCKHEIM (1979) and LOCKE (1979).

Soils on moraines older than those at sites 4 and 13c have similar or slightly better developed horizonation except for the three oldest sites, 12, 21, and 24, which generally have much thicker, better developed horizons and much more organic material in the upper 25 cm of the soil profile (Table II). These moraines have been weathered for a much longer time than those farther up-valley, and may be at least as old as early Holocene.

Holocene soil development on moraines in this study area appears similar to that on moraines of Holocene age on Cumberland Peninsula (BIRKELAND, 1978; BOCKHEIM, 1979; DAVIS, 1980). However, no attempt is made here to correlate moraines between the two areas on the basis of soil development.

DISCUSSION

Possible correlations of moraines in this study with moraines in the Cumberland Peninsula, approximately 800 km north of Labrador, are suggested by the similarity in the minimum diameters of the largest *R. geographicum s. l.* thalli found on moraines in the two areas (Table III). These correlations assume similar lichen growth rates in each area. The validity of this assumption has not been demonstrated. However, the growth rate found for *R. geographicum s. l.* on the northern Cumberland Peninsula (MILLER, 1973) is very close to that established for many other arctic and alpine regions of the world (LOCKE and others, 1980). It is unlikely that the growth rate of *R. geographicum* in the alpine area of northern Labrador is much different than the rate established for this species on the Cumberland Peninsula given the similarity of the alpine environments and the climatic regimes at the altitudes of the present-day glacier termini in each area. If the assumption of similar lichen growth rates in the two areas is correct, the Torngat Mountain area has moraines correlative to moraines of the Cumberland I, II, III, and the Pangirtung

TABLE III

Minimum diameters (mm) of maximum Rhizocarpon geographicum *thalli found on moraines in northern Cumberland Peninsula (MILLER, 1973, 1975) and southern Cumberland Peninsula (DAVIS, 1980), Baffin Island and in the Torngat Mountains of northern Labrador (this study). Grouping of Cumberland Peninsula lichen sizes are from DAVIS (1980). Names events are for the Cumberland Peninsula. Possible correlations with events in the Torngat Mountains are suggested, assuming similar lichen growth rates.*

		Lichen diameters (mm)		
Event	Estimated Age[a]	N. Cumberland Peninsula	S. Cumberland Peninsula	Torngat Mountains
Cumberland I	<150	0-15	0-12	0-14
Cumberland II	200-400	20-25	17-26	25
Cumberland III	500-800	31-35	28-32	29-34
Pangirtung	900-1150	41-44	39-46	41
Dorset	1500-1600	55-58	—	—
Kingnait I	1850-2050	67-70	68-69	⩾67[b]
Kingnait II	2200-2400	80[c]	75-80	>67[d]
Snow Creek	2900-3100	95-100	95-100	⩾91-92[b]
unnamed	3600-3800	115?	120	⩾122[b]

[a] estimated age is from DAVIS (1980, p. 64) based on a modification of lichen growth curve of MILLER (1973).
[b] lichen is acircular with indistinct margin, thallus may have been eroded.
[c] MEARS, 1972.
[d] moraine is immediately downvalley from moraine with 67 mm lichen.

advances of Cumberland Peninsula. Moraines correlative to moraines of the Dorset advance of northern Cumberland Peninsula (MILLER, 1973, 1975) were not found in southern Cumberland Peninsula (DAVIS, 1980) nor in the Torngat Mountains. Moraines possibly equivalent to the moraines of the Kingnait and Snow Creek advances of the Cumberland Peninsula (DAVIS, 1980) were found in the Torngat Mountains. These correlations suggest the possibility of a general synchroneity of climate change between northern Labrador and the Cumberland Peninsula during the late Holocene.

Possible dates of moraine abandonment in the Torngat Mountains are <150, 400, 550-750, 950, $\geqslant 1850$, >1850, $\geqslant 2800$, >2800, $\geqslant 4000$, and $>> 4000$ yr BP (Table I). These dates are based on the Cumberland Peninsula growth curve for *R. geographicum* of MILLER (1973, 1975) as slightly modified by DAVIS (1980). An uncertainty of $\pm 20\%$ should be assigned to dates derived from that curve (MILLER, 1973). Of course, additional uncertainty exists in the dates presented here because of the possibility of a different growth rate for *R. geographicum* in the area of this study.

The oldest moraines considered in this study (sites 12, 21, and 24; fig. 2) have relatively well-developed soils and indicate ice twice as extensive as the next younger moraines (Fig. 2), which are at least 4000 years old based on lichenometry. The moraines at sites 12, 21, and 24 may be at least as old as early Holocene, perhaps 8000 yr BP or older.

CONCLUSIONS

Evidence exists for the retreat of glaciers from the positions of several stillstands or readvances in the Torngat Mountains during the Holocene. The ages of the moraines deposited prior to each retreat remain uncertain. Only tentative correlations of the moraines can be made with moraines on Cumberland Peninsula, Baffin Island. The use of lichenometry for dating moraines greater than about 1500 years old in this area may be limited by boulder surface weathering. Other relative-age data can be used to differentiate older moraines.

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