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THE RAISED BOGS OF SOUTH-EASTERN LABRADOR, CANADA: CLASSIFICATION, DISTRIBUTION, VEGETATION AND RECENT DYNAMICS

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SUMMARY

(1) The mires of Labrador form a distinct geographical zonation: concentric raised bogs occur at low altitudes along the southern coast, excentric and plateau bogs extend inland to slightly greater altitudes and higher latitudes, and patterned fens occupy most of the interior north to the tundra.

(2) The zone boundaries parallel contours and climatic isopleths, and the zonation is explained in terms of the effects of moisture surplus, soligenous water flow and physiography on mire development.

(3) The raised bogs are similar to oceanic mires, with an extensive ground cover of *Cladonia* spp., absence of trees on the mire expanse, and pronounced surface patterns of broad peat hummocks and open-water pools. Three floristic noda are recognized in the phytosociological table: *Cladonia stellaris–C. rangiferina–Kalmia angustifolia* nodum on raised hummocks and *Sphagnum rubellum–Scirpus cespitosus* and *Sphagnum lindbergii–Scirpus cespitosus* noda in hollows.

(4) As a result of the extensive cover of lichens the hummock vegetation readily burns during lightning fires, which are prevalent on the uplands. Examination of a chronosequence of stands burned in 1898, 1931, 1959 and 1975 documents the rapid resprouting of most vascular species and a gradual succession of *Cladonia* spp. and bryophytes.

(5) The recent history of the hummock vegetation involves the alteration of *Cladonia stellaris* and *Sphagnum fuscum*, as documented by the presence of recurrence surfaces in short cores, peat monoliths, and long cores. Local factors, including fire and the lowering of the water table through pool drainage, are frequently responsible for changes in the ground cover and the degree of peat humification, and they may confound the stratigraphic interpretation of climatic change.

INTRODUCTION

The development and geographic distribution of peatlands is largely controlled by regional factors, including climate, geology, and physiography. As peatlands develop and thick accumulations of peat reduce the importance of topography and chemistry, the regional differences in mires begin to reflect the climatic regime (Damman 1979a; Sjörs 1983). The close relationship between climate and mire zonation was recognized in early studies from Finland, where the northward latitudinal zonation of the major mire types consists of unpatterned plateau bog, concentric bog, excentric bog, and minerotrophic fen (Paasio 1939; Eurola 1962; Ruuhijärvi 1960).

In North America much of the basic description and classification of mires in terms of the established European terminology is still lacking. With the exception of Minnesota and the Maritime Provinces of Canada, little attention has been given to an analysis of mire development and distribution in relation to known climatic and landscape features. In Labrador early studies reported that ombrogenous bogs were absent (Wenner 1947;

Allington 1961), whereas recent aerial photographs and aerial observations suggest that ombrogenous bogs are not only a prominent feature of the coastal regions but form a fairly sharp border with the predominantly minerotrophic mires in the interior and north.

This study was initiated to provide a general classification of the mire types and vegetation in south-eastern Labrador and to investigate the factors responsible for the zonal distribution. In places where the transition from ombrotrophic to minerotrophic mire was fairly sharp, it was possible to examine in more detail the importance of local factors in controlling the development and differentiation of the mires. As a further evaluation of the interplay among factors operating at different spatial scales, changes in the vegetation documented in short cores were examined in the light of information on climatic history, the developmental processes involved in surface-pattern formation, and fire history.

THE STUDY AREA

Located on the north-eastern coast of Canada, Labrador belongs politically to the Province of Newfoundland and, geographically, occupies a portion of the Labrador–Ungava Peninsula, which it shares with the Province of Quebec. Labrador forms the eastern part of the Precambrian Canadian Shield, and the bedrock is predominantly quartzo-felspathic gneisses with intrusions of granite and granodiorites (Greene 1974). The entire region was covered by the Laurentide ice sheet; retreat from coastal positions commenced approximately 12 000 B.P. (Ives 1978).

The climate is characterized by long cold winters and short cool summers, with a mean annual temperature of approximately 0 °C. The approximately 1100 mm precipitation is distributed evenly through the year and is among the highest for the North American boreal forest region (Peach 1975).

South-eastern Labrador is covered by extensive forests of black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*), with local areas of lichen woodland, paper birch (*Betula papyrifera*) and patterned peatlands adding variability to the landscape (Foster 1983, 1984b). The significant extent of peatlands in this remote region has been noted from both field studies (Tanner 1944; Wenner 1947) and aerial surveys (Hare & Taylor 1956; Hare 1959; Lopoukhine, Prout & Hirvonen 1977), but the aerial surveys were insufficiently detailed to distinguish between ombrotrophic bog and minerotrophic fen. Thus Damman (1979b) pointed out the conspicuous absence of reliable data on the occurrence of raised bogs at their north-eastern continental limits in south-eastern Labrador.

METHODS

After the compilation of a map of the mire zonation of southern Labrador, eight mires were selected for field studies during September 1981 and July–August 1982.

Mire distribution and zonation

The regional zonation of mires was interpreted and mapped from aerial photographs (1 : 60 000 black and white, Canadian National Air Photograph Library), supported by extensive field observations (Foster 1983; Foster & King 1984; Glaser & Foster 1984). Raised bogs and patterned fens were differentiated on the aerial photographs on the basis of the orientation and shape of peat ridges, hollows and pools, by the hydrology, and by the presence of abundant lichen cover on bogs (Sjörs 1961a; Eurola 1962; Ivanov 1981). Raised bogs were further classified according to their gross morphology (*Grossformen sensu* Aario (1932) and Eurola (1962)) as plateau, excentric, or concentric types (see

Results for further definition of these types). All peatlands on the aerial photographs were mapped by type on 1:250 000 topographic maps. Regional mire zones were then distinguished by the predominance of a particular mire type.

For south-eastern Labrador the percentage of land occupied by mires, as well as the topographic roughness of the landscape, was mapped to document the relationship between physiography and mire development. The 1:250 000 topographic base maps were first overlain with the Universal Mercator Transverse grid system, with each grid square measuring 10 × 10 km. The percentage of each grid square occupied by mires was estimated to the nearest 10% from maps and from 1:60 000 aerial photographs. Topographic roughness, which is an estimate of the amount of relief in an area, was calculated from a count of the number of contour lines crossed by the two diagonals of a grid square. Maps were generated from the data arrays with the BASIC programs MAPFILE and MAPGEN.

Site selection and vegetation analysis

Eight raised bogs were selected to cover both the latitudinal and the coastal–inland gradients in south-eastern Labrador. The sites included plateau bogs (Alexis, Eagle A, Gilbert, Lake Melville, Reticulate, and Sandwich), one excentric bog (Eagle B), and one transitional mire complex (Ranger, Fig. 1).

The vegetation was sampled according to the phytosociological methods of Braun-Blanquet (Mueller-Dombois & Ellenberg 1974). All plant species were recorded in thirty-four 5 × 5 m plots subjectively placed in homogeneous stands of vegetation. Visual estimates of cover-abundance were assigned on a seven-point cover abundance scale.

The thirty-four relevés were sorted and a phytosociological table (Table 1) compiled according to standard procedures (Mueller-Dombois & Ellenberg 1974). An additional

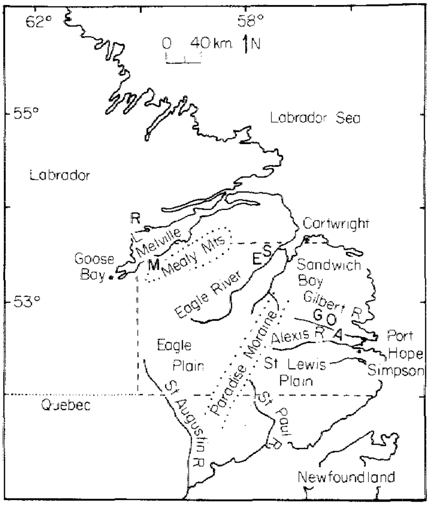

Fig. 1. Map of south-eastern Labrador. Symbols for mires investigated: A, Alexis (52°36′N, 56°43′W); E, Eagle A and B (53°27′N, 57°27′W); G, Gilbert (52°44′N, 56°52′W); M, Lake Melville (53°25′N, 59°35′W); O, Reticulate (52°47′N, 56°45′W); S, Sandwich (53°30′N, 57°31′W); R, Ranger (53°55′N, 59°50′W). The dashed line (---) encloses the region depicted in Figs 12 and 13.

TABLE 1. Phytosociological table of relevés from raised bogs in south-eastern Labrador.

	Cladonia stellaris–Cladonia rangiferina–Kalmia angustifolia Nodum																*Sphagnum rubellum–Scirpus cespitosus* Nodum									*Sphagnum lindbergii–Scirpus cespitosus* Nodum								
Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Number of species	19	24	26	23	23	22	26	27	24	17	21	23	25	26	18	24	14	15	16	13	13	14	15	15	19	15	12	13	16	13	15	13	13	15
Mylia anomala	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.
Vaccinium vitis-idaea	.	1	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia arbuscula	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Larix laricina	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Vaccinium uliginosum	.	.	+	.	.	.	2	2	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ochrolechia sp.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia pleurota	.	.	.	.	.	r	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. deformis	.	.	.	.	.	.	.	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. gracilis	.	+	.	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. macrophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum fallax	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.
S. angustifolium	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	+	.	.	.	.
Cladonia uncialis	.	+	.	.	r	.	.	r	r	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. coccifera	.	r	.	.	.	.	.	.	.	.	.	r	.	r	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. chlorophaea	.	r	r	.	+	.	r	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. maxima	.	.	.	r	.	r	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. mitis	.	+	1	.	.	.	.	.	.	.	+	2	r	2	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polytrichum strictum	.	.	.	.	.	.	r	+	.	.	.	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cetraria islandica	r	r	.	.	.	.	1	.	.	.	.	.	.	.	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. nivalis	r	+	+	r	.	.	.	r	.	r	+	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. arenaria	.	.	2	.	.	.	+	1	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	+	.	.	.	.	.
Icmadophila ericetorum	.	.	r	.	.	.	.	r	r	.	.	r	.	+	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia sulphurina	r	.	.	.	.	.	r	+	.	+	+	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. cornuta	.	+	+	+	+	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. cenotea	.	.	.	r	r	.	+	r	.	r	+	+	.	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pleurozium schreberi	.	+	1	.	+	r	r	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ptilidium ciliare	1	.	.	+	r	.	r	r	+	+	+	.	1	r	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladonia crispata	.	r	.	r	r	+	+	+	+	.	+	+	+	r	r	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.	.
Empetrum nigrum	.	.	.	.	.	1	+	+	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaccinium angustifolium	.	.	.	+	+	+	+	+	+	.	+	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 1—*continued*

	Cladonia stellaris–Cladonia rangiferina–Kalmia angustifolia Nodum																*Sphagnum rubellum–Scirpus cespitosus* Nodum									*Sphagnum lindbergii–Scirpus cespitosus* Nodum								
Picea mariana	2	3	1	+	1	2	+	1	1	.	.	+	1	+	2	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Sphagnum nemoreum	r	+	1	1	1	1	.	1	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Kalmia angustifolia	2	2	1	3	3	3	3	+	4	3	3	4	4	2	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ledum groenlandicum	2	3	2	2	+	+	1	2	2	2	2	2	3	2	3	1	.	.	r	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.
Rubus chamaemorus	+	1	+	1	1	+	.	+	+	+	+	+	1	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	r	.	.	.	.
Cladonia rangiferina	3	3	3	2	3	2	2	2	2	3	3	3	3	1	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. stellaris	3	3	3	4	4	4	5	3	3	3	4	3	4	3	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum fuscum	+	1	1	1	1	2	1	2	2	1	.	1	1	r	1	4	.	.	r	1	r	1	.	+	.	.	.	.	.	.	.	.	.	.
Dicranum undulatum	r	.	1	+	+	+	+	1	+	r	+	+	+	+	1	1	.	.	+	.	+	+	r	.	r	.	.	.	.	.	.	.	.	.
Kalmia polifolia	.	.	r	1	1	+	1	2	1	+	1	1	+	1	+	+	.	+	+	+	.	1	+	+	+	+	.	.	1	.	3	+	1	+
Vaccinium oxycoccus	+	+	r	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	1	+	2	2	2	2	3	+	+	+
Eriophorum spissum	.	+	r	+	+	1	1	1	+	.	.	.	+	+	1	+	2	+	1	3	2	.	1	3	.	.	4	4	.	1	4	+	2	+
Chamaedaphne calyculata	2	2	1	2	2	1	1	2	1	2	2	2	2	3	1	4	+	1	1	1	1	1	1	1	2	1	2	3	4	2	3	+	1	+
Scirpus cespitosus	+	.	1	+	+	+	+	+	+	+	+	+	+	+	.	1	3	3	4	3	2	2	4	3	.	+	2	2	4	2	2	3	3	3
Drosera rotundifolia	1	+	+	+	+	.	.	.	.	.	+	.	+	.	.	.	+	+	+	.	.	+	+	+	.	+	1	+	1	.	+	+	+	+
Sphagnum rubellum	r	.	.	.	.	.	.	.	.	.	.	1	1	+	.	1	4	4	5	5	4	5	3	3	3	1	.	.	+	.	4	2	2	1
Cladopodiella fluitans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	+	1	1	1	1	1	+	1	1	1	1	1	2	1	1	1	2
Carex limosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	3	+	1	+	2	2	1	2	.	+	1	1	1	1	.	.	2	2
Andromeda glaucophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	+	2	1	1	1	1	.	2	1	2	2	1	1	1	1	+
Sphagnum tenellum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	+	2	2	1	.	1	1	1	1	1	2	3	+
S. magellanicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	r	3	.	.	.	1	1	.	.	r	.	1	.	3	+
S. papillosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	.	.	.	1	r	.	1	.	.	.	.	1
S. lindbergii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	1	1	.	.	1	.	3	5	4	3	3	1	4	3	5
Sarracenia purpureus	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	+	+	.	.	+	+	+	+	+	.	.	.	.	+	+	.	.
Cephaloziella sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	r	.	r	+	.	.	.	.	.	+	.	.
Drepanocladus fluitans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	3	.	.	.	+	.	.	.	+
Sphagnum pulchrum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	2	.	.	.

Additional species (relevė number, cover value). *Gaultheria hispidula* (78, +), *Drosera anglica* (88, +), *Nuphar variegatum* (64, +), *Eriophorum russeolum* (68, 4), *Smilacina trifolia* (68, +; 65, 1), *Carex pauciflora* (68, 2), *Carex paupercula* (68, 2), *Carex livida* (65, 3), *Menyanthes trifoliata* (65, 1), *Scheuchzeria palustris* (65, +), *Carex oligosperma* (65, 4).

Cover-abundance symbols: r, single occurrence; +, sparsely present; 1, plentiful but small cover value; 2, very numerous or covering 1/20 of area; 3, any number of individuals covering 1/4–1/2 of area; 4, any number of individuals covering 1/2–3/4 of area; 5, covering more than 3/4 of area.

fifteen relevés were taken from burned hummocks to examine the impact of fire on the mire vegetation. These relevés, which were located on 1898, 1931, 1959 and 1975 burns, are arranged in Table 2.

TABLE 2. Phytosociological table of post-fire bog hummock vegetation in south-eastern Labrador.

Year of fire	Unburned			1898			1931			1959			1975		
Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of species	23	27	24	26	25	23	26	28	29	23	26	25	10	13	12
Dicranum undulatum	1	+	+	r	.	+	.	.	.	.	.	.	.	.	.
Empetrum nigrum	+	1	+	.	r	.	.	.	.	.	.	.	.	.	.
Ptilidium cilare	.	+	1	r	.	+	.	.	.	.	.	.	.	.	.
Cetraria islandica	.	r	.	.	.	+	.	.	.	.	.	.	.	.	.
Larix laricina	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.
Mylia anomala	1	.	+	.	+	.	.	.	.	.	r	.	.	.	.
Vaccinium vitis-idaea	.	1	+	+	.	.	.	.	.	.	.	.	.	.	.
Cetraria arenaria	1	.	+	.	+	.	.	.	r	.	.	.	.	.	.
Cladonia cenotea	+	.	.	r	+	.	.	r	.	.	.	.	.	.	.
Cetraria nivalis	r	.	.	.	r	.	.	2	.	.	.	.	.	.	.
Cladonia stellaris	5	4	4	3	3	3	1	3	2	.	.	.	.	.	.
Pleurozium schreberi	1	+	.	+	.	+	.	1	.	.	r	.	.	.	.
Drosera rotundifolia	+	+	.	1	.	.	.	+	+	.	.	+	.	.	.
Picea mariana	3	1	2	1	1	+	+	+	.	.	.	r	.	.	.
Cladonia rangiferina	2	1	2	2	3	2	2	2	3	r	.	+	.	.	.
C. mitis	1	.	+	.	1	.	2	3	2	1	r	2	.	.	.
C. crispata	r	r	r	r	+	.	.	r	+	1	r	+	.	.	.
C. cornuta	.	r	.	.	.	r	r	1	+	1	r	+	.	.	.
Sphagnum nemoreum	.	1	1	1	.	1	2	.	r	r	r	1	.	1	.
S. fuscum	2	2	1	1	1	2	1	1	1	r	1	.	.	r	r
Kalmia angustifolia	2	4	2	+	3	1	2	2	2	3	1	2	2	2	2
Ledum groenlandicum	2	3	2	+	2	2	1	2	3	3	2	3	2	3	1
Rubus chamaemorus	1	+	+	+	+	+	+	1	+	+	1	1	2	2	1
Kalmia polifolia	1	+	1	2	r	1	+	+	1	1	1	+	1	1	1
Vaccinium oxycoccus	+	+	+	r	1	+	+	+	+	r	+	.	.	r	+
Eriophorum spissum	.	r	+	+	1	1	+	r	1	.	+	+	+	.	r
Scirpus cespitosus	.	+	+	1	+	1	1	2	+	+	+	+	+	+	+
Chamaedaphne calyculata	2	2	1	1	2	1	2	+	2	1	2	2	3	2	1
Vaccinium angustifolium	+	+	.	2	.	+	.	1	+	.	2	.	.	+	1
Icmadophila ericetorum	.	.	r	.	.	r	r	+	1	r	.	+	.	.	.
Cladonia maxima	.	.	.	.	r	.	+	.	r	.	+	r	.	.	.
C. chlorophaea	.	.	.	.	.	.	r	r	1	2	r	+	.	.	.
C. coccifera	.	.	r	r	r	.	+	+	1	+	1	r	.	r	.
C. uncialis	.	r	.	.	+	+	+	.	+	r	.	.	.	.	.
C. macrophylla	.	.	r	+	.	.	+	1	r	1	r	r	.	.	.
C. gracilis	.	r	.	.	r	.	+	+	r	r	+	+	.	.	.
C. deformis	.	.	.	r	.	.	r	.	.	.	r	r	.	.	.
C. pleurota	.	.	.	.	.	.	r	+	.	r	.	+	.	.	.
C. arbuscula	.	.	.	.	.	r	r	+	.	.	.	.	.	.	.
Vaccinium uliginosum	2	+	.	.	+	1	.	.	+	.	+	.	.	.	.
Cladonia sulphurina	.	.	.	.	r	.	.	.	r	2	+	1	r	.	.
Polytrichum strictum	r	.	.	r	.	.	r	+	1	1	r	2	3	2	1
Lecidea granulosa	.	.	.	.	.	.	.	.	r	1	2	1	3	1	2

Cover abundance symbols: r, single occurrence; +, sparsely present; 1, plentiful but small cover value; 2, very numerous or covering 1/20 of area; 3, any number of individuals covering 1/4–1/2 of areas; 4, any number of individuals covering 1/2–3/4 of area; 5, covering more than 3/4 of area.

A set of voucher samples of lichens is deposited in the Herbarium of the University of Minnesota. Duplicates of all bryophyte collections are stored in the National Herbarium, National Museum of Canada. Nomenclature follows Fernald (1970) for vascular species, Ireland *et al.* (1980) for mosses, Stotler & Crandall-Stotler (1977) for liverworts, and Hale & Culberson (1970) for lichens except *Cladonia*, which follows Ahti (1961).

Water chemistry

Water samples were collected at all relevés. At Ranger Mire samples were also taken from all open-water pools on the bog plain and on the adjoining minerotrophic fen. At each site an acid-washed 250-ml polypropylene bottle was rinsed three times with water from the site before a sample was taken. Acidity was measured in the field or within 5 h of collection with a Radiometer pH meter equipped with a combination glass–calomel electrode. Calcium concentrations were determined by spectrophotometry.

Peat stratigraphy

Long cores of peat were taken at Eagle A and Ranger bogs with a piston sampler 10 cm in diameter equipped with a serrated cutting edge (Wright, Mann & Glaser 1984). The cores were used for obtaining basal radio-carbon dates, which were processed at the University of Wisconsin Radio-carbon Laboratory. For all relevés the near-surface stratigraphy was examined on monoliths cut with a serrated knife. The cores and monoliths were described and photographed in the field, wrapped in plastic and aluminium foil, and transported to the laboratory.

Topographic survey and mapping

Ranger Mire, a mire complex with both ombrotrophic and minerotrophic areas, was mapped from aerial photographs taken with a 35-mm camera from a helicopter at a height of 1000 m. Scale was provided by ground measurements. To record the topography of the bog plain and adjoining fen, a theodolite was placed in a central location, and the height of the surfaces of all open-water pools within a radius of approximately 350 m were recorded.

RESULTS

Classification of raised bogs

Three distinct types of raised bog (concentric, excentric, plateau) may be distinguished in south-eastern Labrador on the basis of gross morphology and the arrangement of surface features, primarily hummocks, hollows and pools. All are similar to the oceanic mires described by Damman (1977) in that they lack trees on the mire expanse, contain pronounced surface patterns, and have an extensive cover of *Cladonia* spp.

A concentric raised bog (*konvexes Hochmoor—sensu* Eurola (1962)) is characterized topographically by a central peat cupola that slopes approximately evenly in all directions to the surrounding mineral soil. The surface morphology is controlled by the overall relief and consists of concentrically arranged hummocks and shallow hollows (Fig. 2). In an excentric bog (*konvexes konzentrisches Hochmoor*) the peat dome is greatly offset from the centre of the mire, and the axes of the mire are, therefore, unequal in length (Fig. 3). The surface morphology is marked by weakly developed patterns along the short axis, and a pronounced pattern of alternating hummocks and hollows is arranged perpendicular to the slope of the long axis. The concentric and excentric mires are generally less than a few square kilometres in size.

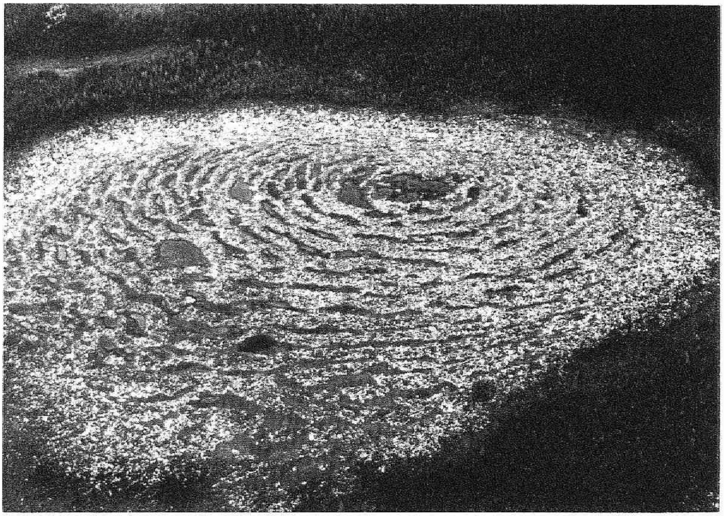

FIG. 2. Oblique aerial photograph of a concentric bog along the Eagle River, south-eastern Labrador. Shallow pools, arcuate hollows, and hummocks covered with *Cladonia stellaris* are arranged in a concentric pattern over the central peat dome. Black spruce forest occupies the upland margins of the mire, which is approximately 300 m in width. Photograph by D. R. Foster.

A plateau bog (*kermihochmoor*) has a relatively steep, unpatterned rand that rises 1–3 m to the level expanse of the open mire, which may cover many square kilometres. The wide hummocks that predominate on the central plateau are interrupted by broad, unoriented pools, which may cover more than half of the mire to form an intricate reticulate pattern (Figs 4 and 5). The extensive plateau mire on the terrace south-west of Lake Melville is approximately 30 × 10 km in area, forming the largest continuous peatland in Labrador.

Mire zonation in south-eastern Labrador

The mires of south-eastern Labrador display a pronounced regional zonation (Figs 6 and 7). Ombrotrophic raised bogs occupy a coastal zone that tapers in breadth to the north, whereas patterned fens are mainly located inland and increase in prominence at higher latitudes. Near Port Hope Simpson the raised bog zone exceeds 100 km in breadth. North of Sandwich Bay the zone is reduced to a strip less than 50 km wide bordering Lake Melville. On the north-eastern coast the raised bogs are confined to protected bays as far north as approximately 55 °N—the north-eastern limit of raised bogs in North America.

Inland from the raised-bog zone, patterned fens (*aapamires sensu* Cajander (1913)) cover extensive areas across central and western Labrador (Allington 1961; Foster & King 1984) and north to the tundra, where palsa mires predominate (Brown 1979). At the border between the raised-bog and patterned-fen zones, there is a region of variable width occupied by transitional mire complexes, which contain extensive though discrete areas of bog and fen (e.g. Ranger Mire, Fig. 14).

Additional mire types occur in the discontinuous tundra that fringes the Labrador coast (Hustich 1939). Here the cool temperatures, frequent cloudiness and exposure to wind restrict productivity and limit mire development. Shallow unpatterned fens occur in this

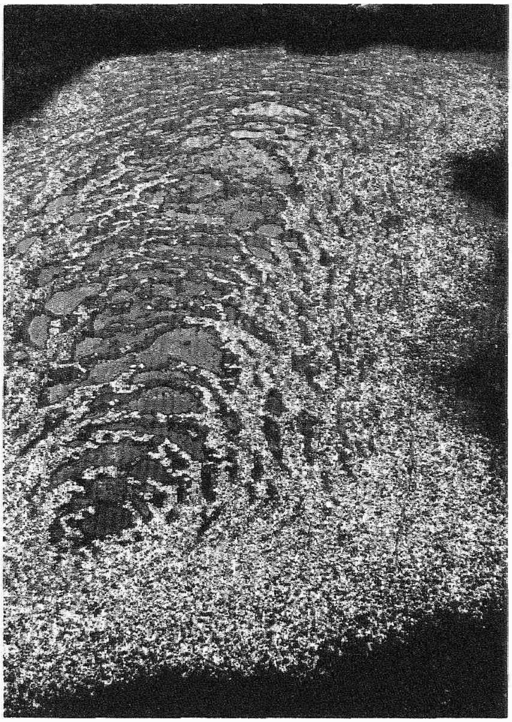

FIG. 3. Oblique aerial photograph of an excentric mire—Eagle B, south-eastern Labrador. The highest point on the mire is offset from the centre, producing one short unpatterned axis and one long axis occupied by alternating linear hummocks and elongated pools. Total length of the mire is approximately 400 m. Photograph by D. R. Foster.

zone, and palsas are located along the eastern coast, near Sandwich Bay, and on the islands in Lake Melville (Hustich 1939; Wenner 1947; Brown 1979).

Relationship between mire zonation and regional features

Topography

The distribution of mire types largely follows the contours, with a gradual decrease in the altitude of the bog–fen transition from south to north (Fig. 8). On the north shore of the Gulf of St Lawrence and near Sandwich Bay the transition occurs at 300 m or more and on the north shore of Lake Melville at 150 m. The northern limit of raised bogs is apparently formed by small plateau mires at altitudes of less than 30 m at Adlavik and Ugjoktok Bay.

Climate

Mean annual precipitation increases along a gradient inland from the coast, with maximum levels exceeding 1300 mm on the southern border with Quebec (Fig. 9) (Peach 1975; Banfield 1981). A similar gradient for annual snowfall results in approximately

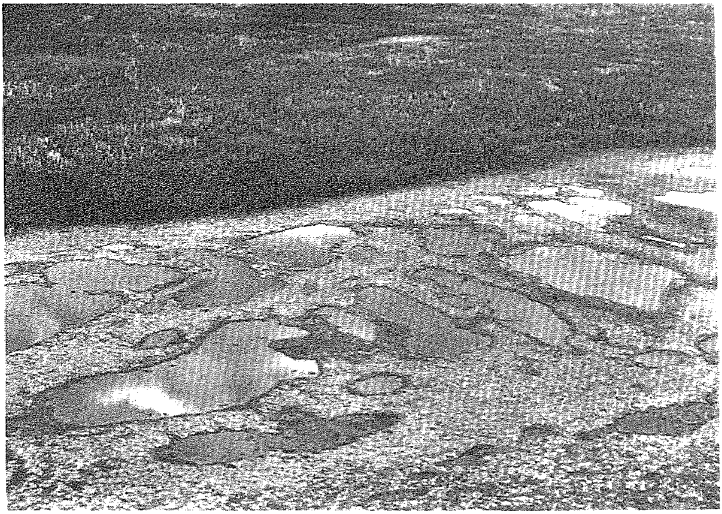

FIG. 4. Oblique aerial photograph of a plateau bog on a terrace along the Alexis River, south-eastern Labrador. The broad pools are separated by wide ridges covered with *Cladonia stellaris* and *Sphagnum fuscum*. Evidence of the coalescence of adjacent pools is seen near the left margin, where a broken peat ridge extends part-way between joined pools. Photograph by D. R. Foster.

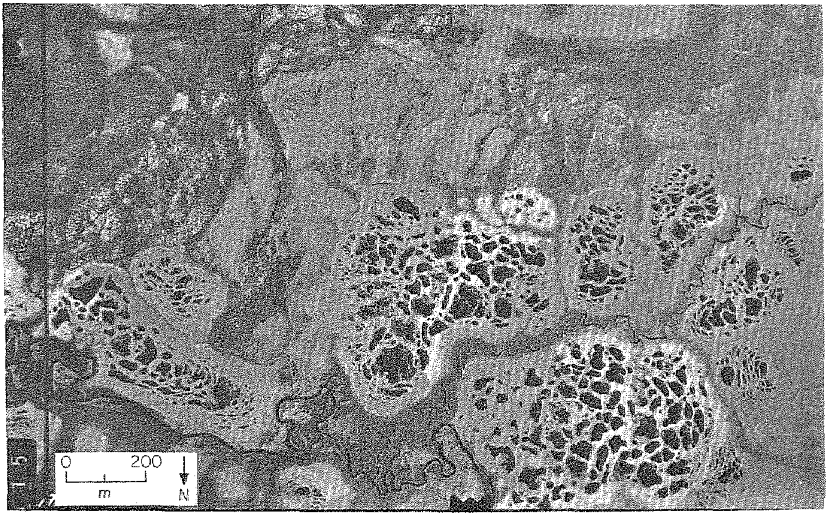

FIG. 5. Reticulate mire south-eastern Labrador—a spectacular example of a plateau bog which was burned in 1959. Gray burned areas on the mire and adjacent upland contrast with light, lichen-covered regions in the north-west and centre of the mire. The individual mires are separated by meandering streams. Smaller streams can be seen cutting from the margin towards the centre of each bog and draining some of the pools. Photograph from *Canadian National Air Photo Library*.

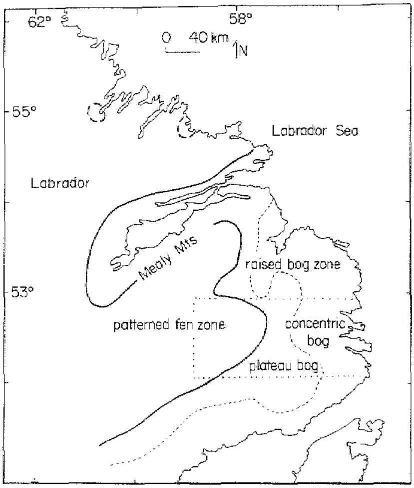

FIG. 6. Peatland zonation in eastern Labrador. Within the raised-bog zone concentric bogs are concentrated along the south-eastern coast, whereas plateau bogs and excentric bogs extend farther inland and to the north. The dotted line encloses the extent of Fig. 3.

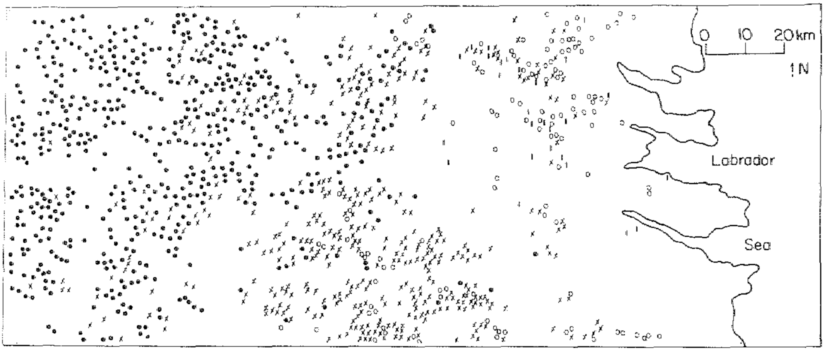

FIG. 7. The detailed distribution of mires in south-eastern Labrador. Symbols: (●), string fen, (×) plateau bog; (O) excentric bog; (|) concentric bog.

300–400 cm along the coast and more than 500 cm in the interior (Fig. 10). Mean annual temperature decreases inland; Goose Bay and the eastern coast averages approximately 0 °C, whereas the central plateau is below −2·5 °C (Fig. 11).

The separation between fen and raised bog in south-eastern Labrador corresponds approximately to the 1100-mm precipitation isopleth. Overall, there are pronounced climatic differences between the regions supporting different mire types. Coastal Labrador experiences a more equable climate than the interior, with cooler summers, slightly warmer winters, and less precipitation (Peach 1975; Banfield 1981). Because of the rapidly diminishing influence of maritime air inland, the interior has a more continental climate

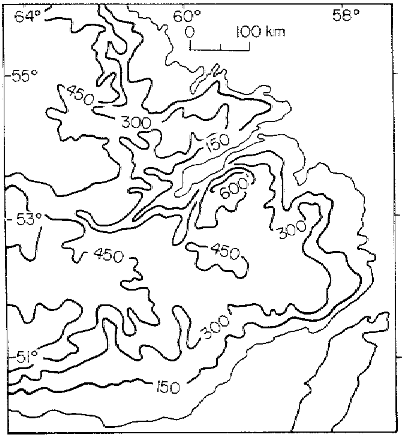

FIG. 8. Topographic map of eastern Labrador with contours in metres.

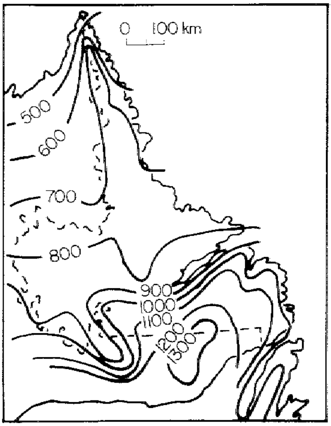

FIG. 9. Isopleths of annual precipitation (mm) for Labrador and adjacent Quebec. Modified from Banfield (1981).

than the coast (Bryson 1966). It also has lower mean annual temperatures and higher precipitation as a result of its greater altitude.

Physiography

Mires cover an average of about one-quarter of south-eastern Labrador (Fig. 12), but the distribution is highly variable and is largely controlled by the local relief (Figs 12 and 13). In addition, the physiography influences the distribution of mire types, especially in the transitional zone between raised bog and fen. Mires cover 60–90% of the St Lewis plain (Fig. 12), which lies to the east of the Paradise moraine and is extremely flat and relatively featureless (Fig. 1). The mires there are primarily plateau bogs and transitional mire

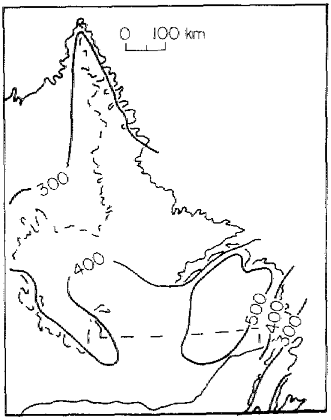

FIG. 10. Isopleths of annual snowfall (cm) for Labrador and adjacent Quebec. Modified from Peach (1975).

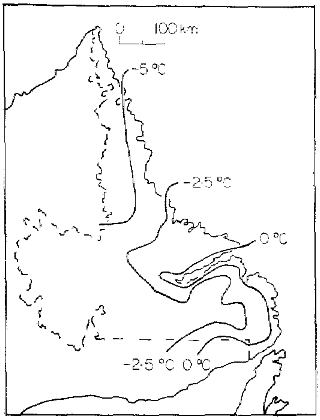

FIG. 11. Isopleths of mean annual temperature (°C) for Labrador and adjacent Quebec. Modified from Banfield (1981).

complexes, in which the bogs occupy the water divides and patterned fens occupy seepage zones downslope. To the west of the moraine, the Eagle plain is composed of a drumlin field that fans out over a 150° arc. The mires there are nearly all minerotrophic fens, which occupy shallow drumlin troughs and drainage-ways to form extensive complexes (Foster & King 1984).

In the extreme north-west the L. Melville mire is a largely ombrotrophic complex, approximately 300 km^2 in area, which blankets a gently sloping marine terrace (Figs 12 and 13). In the north-east a small glacial plain supports a confined area of mire between the coast to the east and hilly topography to the west.

Areas which lack extensive mire deposits are either topographically rough, or in exposed situations at high altitude, or within the barren coastal-tundra zone (Figs 12 and 13). Three

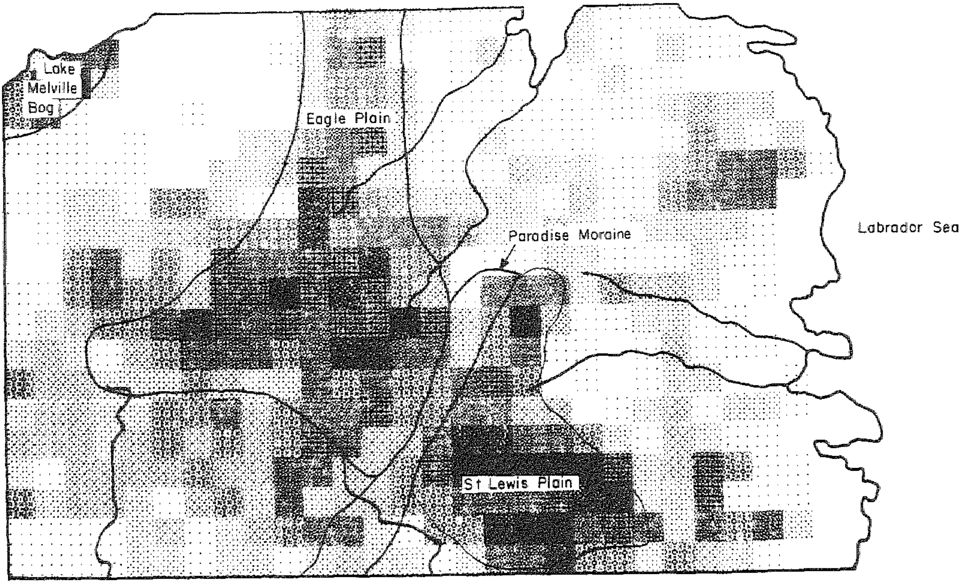

FIG. 12. Percentage of mires on the land surface in south-eastern Labrador. The darker shades indicate a higher percentage of mire, with white equal to 0–10%, black equal to 91–100%. Each square is 10 × 10 km.

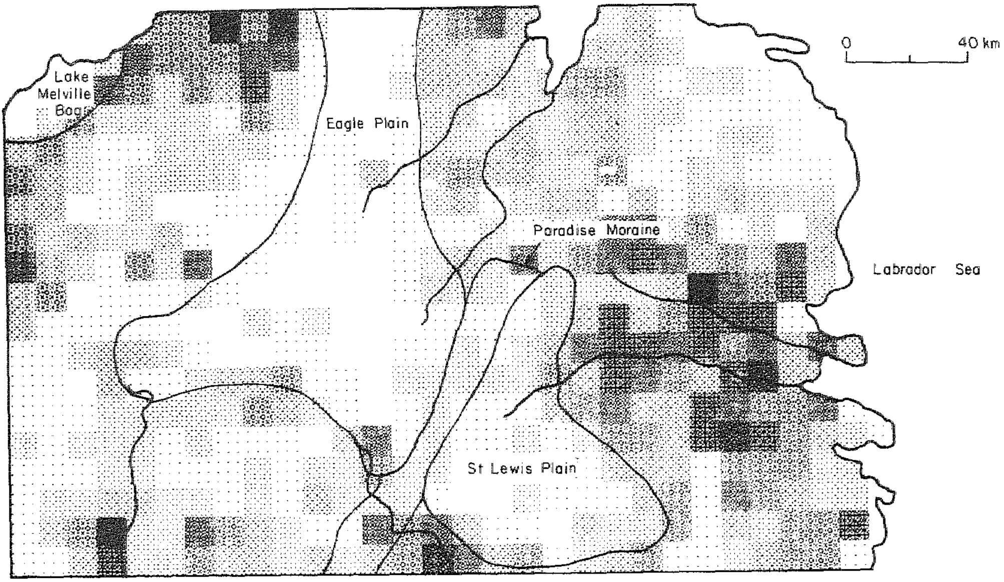

FIG. 13. Surface roughness in south-eastern Labrador. White areas are flat whereas darker shades indicate increasingly rougher topography. See Methods for details. Each square is 10 × 10 km.

distinct regions of dissected or hilly terrain occur: the Mealy Mountains to the north-west; the down-cut edges of the plateau along the Alexis and St Lewis River valleys to the east; and the St Augustin and St Paul River valleys to the south and south-west (Figs 1 and 9). Within the river valleys, large areas for mire development occur only along glacial-outwash terraces or abandoned drainage-ways. The terraces, which may exceed 0·5 km in width and extend for many kilometres upstream, are largely covered by plateau bogs (Figs 4–6). Few extensive areas of mire lie within 10 km of the exposed and often rocky coast of south-eastern Labrador.

Topography, water chemistry, and vegetation of a mire complex

Ranger Mire is representative of the transitional mire complexes that occupy a broad area between the bog and fen zones. It consists of a raised-bog plain and two large patterned fens (Fig. 14). The bog occupies a slight rise in the mineral substratum and serves as a water divide, with water flowing principally to the east, south-east and north-west. The fens occupy seepages that flow from the south-western part of the mire and then bifurcate to pass around the bog plain.

Topographically the raised bog is relatively level, although undulating. There is an approximately 40-cm difference in altitude between the various large pools that occupy the main expanse of the crest (Table 3; pools 2–9). Towards the perimeter of the ombrotrophic area, the pools are as much as 120 cm lower, and many are influenced by minerogenic water from the adjoining fens.

The water chemistry and floristics parallel the topography in the distinct separation of the minerotrophic and ombrotrophic portions of the mire complex. On the bog plain the pH of the pools and the relevé sites ranges from 4·0 to 4·5 (Table 3; pools 1–9), whereas

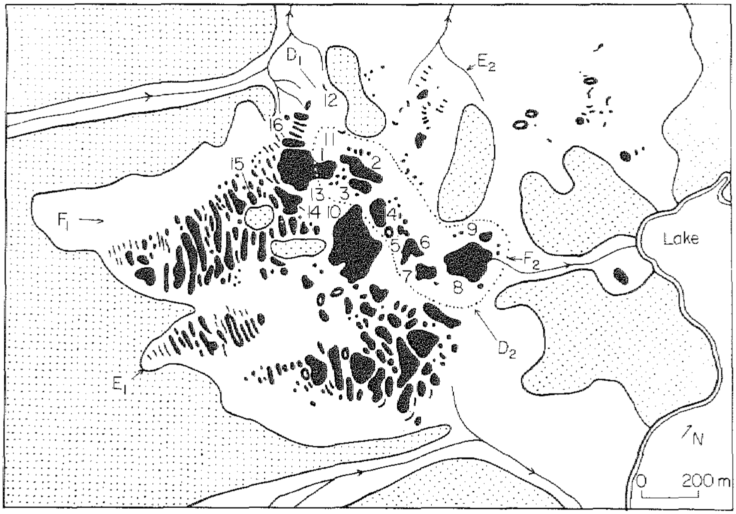

FIG. 14. Map of Ranger Mire, south-eastern Labrador, a transitional mire complex. Symbols: (■), open-water pools; (▦), mineral uplands; the thick continuous lines (○) enclose *Sphagnum* hollows; (·······), encloses the ombrotrophic bog crest; the numbers refer to the pools mentioned in the text and in Table 3. The letters D, E and F are transects along which surface topography and peat depth were measured.

TABLE 3. Characteristics of open-water pools on Ranger Mire, Labrador. Length is the longest dimension, and altitude is the height above the lowest point measured (pool 16).

Pool number	Length (m)	Altitude (cm)	Minerotrophic indicator species*	pH	Ca ($\mu g\ l^{-1}$)
1	60	107	*Mt*	4·4	0·31
2	165	120		4·5	0·32
3	55	133		4·5	0·34
4	95	155		4·5	0·26
5	15	146		4·4	0·18
6	90	152		4·5	0·31
7	70	147		4·4	0·10
8	175	135		4·5	0·18
9	35	132		4·4	0·10
10	260	128	*Cl, Cr, Mt, Ui*	5·1	1·80
11	10	110		4·3	0·31
12	10	105		4·2	0·30
13	155	85	*Bm, Mt*, r	6·3	4·68
14	70	95	*Ce, Da, Js*	6·4	5·52
15	25	90	*Cl, Cs, Da*	5·8	1·80
16	45	0	*Bm, Cl, Da, Mt*	6·0	—

* Minerotrophic indicator species (cf. Sjörs 1948, 1961; Du Rietz 1950; Hosiaisluoma 1975): *Bm, Betula michauxii*; *Ce, Carex exilis*; *Cl, Carex livida*; *Cr, Carex rostrata*; *Cs, Calliergon stramineum*; *Da, Drosera anglica*; *Js, Juncus stygius*; *Mt, Menyanthes trifoliata*; *Ui, Utricularia intermedia*.

r, rocks exposed in bottom of pool.

transitional areas (pools 10, 13), soaks (pool 16), and the fens have pH values ranging from 5·1 to 6·4. Calcium concentrations range from 0·10–0·34 $\mu g\ l^{-1}$ for bog pools to 1·80–5·52 $\mu g\ l^{-1}$ for transitional areas and soaks. The relevés from the bog plain (relevés 3, 27, 28, 30, 31; Table 2) match those from the south-eastern bogs (Glaser & Foster 1984), whereas relevés from the patterned fens are very similar to those from poor fens on the Eagle plain (Foster & King 1984). In the transitional areas (e.g. on the shores of pools 10 and 13) where fen waters have begun to influence former bog pools, there occur scattered minerotrophic indicators (*sensu* Sjörs (1948)) such as (in order of abundance) *Menyanthes trifoliata*, *Betula michauxii*, *Utricularia intermedia*, *Drosera anglica*, *Carex livida*, and *C. rostrata*.

Raised bog vegetation

A total of thirty-four relevés containing fifty-seven taxa are grouped into three noda in the phytosociological table (Table 1). Each nodum is discussed below.

Hummocks

The *Cladonia stellaris–C. rangiferina–Kalmia angustifolia* nodum occupies raised hummocks and ridges and contains an average of twenty-two species. Dominants include *Cladonia stellaris*, *C. rangiferina* and *Sphagnum fuscum* in the ground layer, accompanied by the herbs *Rubus chamaemorus*, *Scirpus cespitosus* and *Vaccinium oxycoccus* and the shrubs *Kalmia angustifolia*, *Chamaedaphne calyculata* and *Ledum groenlandicum*. Differential species include, in order of abundance: *Sphagnum nemoreum*, *Picea mariana*, *Ptilidium ciliare*, *Pleurozium schreberi*, *Vaccinium angustifolium*, and a group of *Cladonia* spp. (*C. cenotea*, *C. crispata*, *C. cornuta*, and *C. sulphurina*).

The hummocks range from 20 cm to 50 cm in height above the water table and cover large portions of the mire surface. *Cladonia* spp. constitute the dominant ground cover, with *C. stellaris* forming patches 5–25 cm thick in open areas and *C. rangiferina* predominating beneath shrubs. The lichen cover rests on *Sphagnum fuscum* peat, but at present the living moss occupies less than 20% of most hummock surfaces. *Sphagnum nemoreum* frequently grows in association with *S. fuscum*, and both are intermixed with the liverworts *Mylia anomala* and *Bazzania trilobata. Icmadophila ericetorum* may form circular depressions on *Sphagnum fuscum*, suggesting an outward growth, killing the *Sphagnum*.

With decreasing height above the water table, there is a decrease in lichen and shrub cover and increase of *Scirpus* and *Carex limosa.* Along this gradient, from hummock to hollow, is also observed the bryophyte zonation: *Sphagnum fuscum/S. nemoreum, S. rubellum, S. magellanicum, S. papillosum, S. tenellum, S. lindbergii.*

Hollows

Hollows and peat flats near the water table are occupied by lawn and carpet vegetation. Frequently these communities occupy the narrow transitions between raised hummocks and pools, but broad areas occur where a pool has been emptied or lowered by the erosion of its damming ridge (cf. Foster *et al.* 1983). The exposed peat surface that formed the bottom of the pool provides a broad, low area on which extensive moss carpets may overlie a loose peat substratum.

Two floristic assemblages in hollows may be differentiated on the basis of dominant species; the floristic composition and the average number of species (15) are identical (Table 1). The *Sphagnum rubellum–Scirpus cespitosus* nodum is distinguished by high cover values of *Carex limosa, Sphagnum rubellum* and *Scirpus cespitosus*, as well as by the frequent occurrence of *Sphagnum fuscum* and *Dicranum undulatum*. In the *Sphagnum lindbergii–Scirpus cespitosus* nodum there occurs a greater abundance of *Vaccinium oxycoccus, Chamaedaphne calyculata* and *Eriophorum spissum*, and much less *Sphagnum rubellum*. Other important species in the two noda include *Drosera rotundifolia, Kalmia polifolia, Cladopodiella fluitans, Andromeda glaucophylla* and *Sphagnum tenellum*.

The *Sphagnum rubellum* nodum occupies a slightly higher position above the water table, and the two communities frequently intermingle on undulating surfaces. Slight differences in microrelief provide some heterogeneity in both noda. Small hummocks may be occupied by *Sarracenia purpureus, Chamaedaphne calyculata, Sphagnum fuscum* and *Cladonia* spp. in the *Sphagnum rubellum* nodum, and by *Andromeda glaucophylla, Vaccinium oxycoccus* and *Cetraria nivalis* in the *Sphagnum lindbergii* nodum. In both noda, depressions may form mud bottoms occupied by *Cladopodiella fluitans, Gymnocolea inflata, Sphagnum pulchrum*, or *S. tenellum*.

Pools

Open-water pools on the mire surface exhibit considerable variation in size and shape, depending on the type of mire, the placement of the pool in the mire, and history of pool development. On excentric and concentric mires the few pools are arcuate and shallow. Generally during a dry summer the water level in the pools drops, and the exposed peat forms a mud bottom that may crack from desiccation. On plateau mires, the pools are generally irregularly rounded in outline, although the coalescence of adjacent pools through the breakdown of the intervening ridge may create uneven, linear patterns (Figs 4 and 5). The largest pool observed exceeded 150 m by 40 m. The margins of the pools are formed of robust peat hummocks that may slope abruptly to the pool bottom 20–300 cm below. On some bogs the pools extend to the underlying mineral soil, and the water is therefore higher in pH and dissolved salts than is the surrounding mire.

The vegetation of pools is extremely sparse and generally consists of scattered *Carex limosa* in the shallows and *Nuphar variegatum* in deep water. Pools enriched by contact with the underlying mineral soil may support such minerotrophic species as *Menyanthes trifoliata, Carex rostrata* and *Sparganium angustifolium*. Beavers (*Castor canadensis*) frequently build lodges on the larger pools and fish are especially common in the richer waters.

The effect of fire on raised bogs

Lightning fires are an important environmental factor in south-eastern Labrador (Foster 1983). As the mires investigated lie within areas burned in 1898, 1931, 1959, and 1975, it was possible to examine the effect of fire on the raised bogs and the recovery sequence of the vegetation. Fires spread easily from the adjoining upland areas through the shrubby and wooded margins of the raised mires. On the bog expanse, fire tends to burn preferentially along the lichen-covered ridges and hummocks, eliminating the lichen cover and killing the conifers and the above-ground portion of other vascular species (Fig. 5). The *Sphagnum* cover is killed apparently by heat rather than by burning, and on the bogs studied there was little removal of peat. As there is little woody biomass on hummocks, the amount of charcoal produced and subsequently incorporated in the peat stratigraphy is minimal.

Burned areas and dead *Sphagnum* generally are colonized by a succession of lichen species in a pattern similar to that of upland sites on deep humus (Foster 1985). In the years immediately following fire the shrubs resprout prolifically, and the charred humus is covered by the crustose lichen *Lecidea granulosa* and by *Polytrichum strictum* (Table 2). On Gilbert Bog, burned in 1959, the discontinuous ground cover is composed of *Lecidea granulosa*, *Cladonia* spp. (*C. sulphurina*, *C. coccifera*, *C. macrophylla*, *C. chlorophaea*) and *Polytrichum strictum*. The lichen *Cladonia mitis* had just appeared on this surface, but on a portion of the bog burned in 1931 it was dominant along with *Cladonia rangiferina*. Another species, *C. stellaris*, apparently increases slowly, but it forms a nearly continuous ground cover on 1898 burns. With the exception of *Empetrum nigrum, Picea mariana* and *Larix laricina*, which are killed by fire (Bell & Tallis 1973; Foster 1985), the vascular species resprout to approximately their original cover within 20 years of burning.

Gross stratigraphy

Long cores

At Ranger Bog two long cores (245 cm and 255 cm) down to the mineral substratum were obtained from hummocks covered with *Cladonia stellaris–C. rangiferina–Kalmia angustifolia* vegetation. The gross stratigraphy in both cores consists of alternating zones of well- and poorly-decomposed *Sphagnum fuscum* peat, extending from the surface to within 30–50 cm of the base, where there is an abrupt transition to well-decomposed sedge peat. The sedge peat continues to mineral soil, where basal dates of 6300 ± 80 B.P. (WIS-1533) and 5940 ± 80 B.P. (WIS-1534) were obtained. These compare with basal dates of 5900–6700 B.P. for peat deposits along Sandwich Bay (Lowden & Blake 1975), 4400 B.P. for basal fen deposits on the Eagle plain (Foster & King 1984), and 10 000–11 000 B.P. for basal lake sediments from eastern Labrador (Lamb 1980). As in other mires in the region, peat did not begin to accumulate in the raised bogs until well after the postglacial forest of spruce and fir had developed at *c.* 7500 B.P.

Short cores

Shallow peat cores and monoliths were obtained to explore the stratigraphic relations and recent dynamics of hummock mosses and lichens. Numerous monoliths were cut from hummocks across the sharp border between *Sphagnum fuscum* and *Cladonia stellaris*. All of the monoliths demonstrate a very dynamic relationship, with frequent changes in abundance of the two species and episodes involving the overgrowth of one species by the other. Four monoliths were selected that are representative of this relationship; monoliths similar in detail were obtained at each bog investigated.

In Fig. 15a the surface cover is composed of *Sphagnum fuscum* and *Cladonia stellaris*. The *Sphagnum fuscum* is actively encroaching on the lichen and forms a wedge overlying partially-decomposed remains of *Cladonia stellaris*. Well-decomposed dark-brown *Sphagnum fuscum* underlies the lichen and provides a sharp contrast to the light-brown preserved moss at the surface.

In Fig. 15b a similar stratigraphy is recognized, with *Cladonia stellaris* extending beneath actively growing *Sphagnum fuscum* to form a narrow zone of decomposed remains. Below the lichen horizon lies a band of very dark, well-humified *Sphagnum fuscum* that is rather distinctly separate from the underlying well-preserved and light-brown *S. fuscum*.

The third monolith, obtained from Ranger Bog, contains two recurrence surfaces (*sensu* Granlund (1932)). In the upper portion of the profile the *Cladonia* sp. is distinguishable (morphologically and chemically) as *C. stellaris* and forms a rather thick, loose horizon. Scattered charcoal fragments (0·1–0·4 cm diameter) occupy the transition to a very dark *Sphagnum fuscum* layer. Below this, well-preserved *Sphagnum fuscum* overlies a lower lichen layer, a thick dark layer, and then less humified *Sphagnum fuscum*. The lower lichen

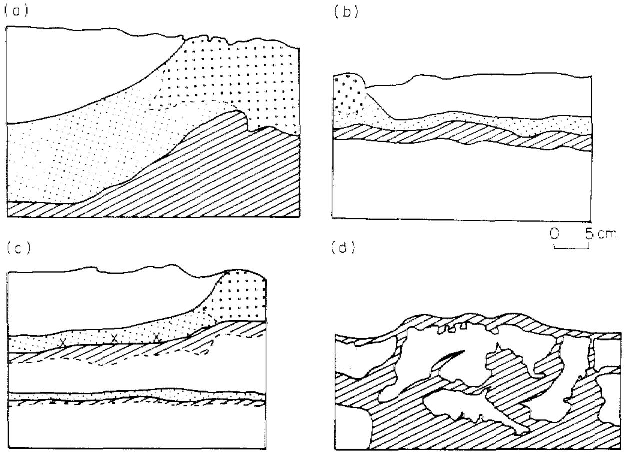

FIG. 15. Near-surface peat stratigraphies from four sites in south-eastern Labrador; a–c, recurrence surfaces involving the alteration of layers of *Cladonia* spp. and *Sphagnum fuscum*; d, humification of peat along frost cracks in a *S. fuscum* hummock following fire. Vertical and horizontal scales are equal. Symbols: □, well-preserved *Sphagnum fuscum*; ▨, well-decomposed *S. fuscum*; ⊡, well-preserved *Cladonia stellaris*; ▦, well-decomposed *C. stellaris*; ×, charcoal.

layer is distinguishable as *Cladonia* sp., but the plants have lost most of their form, coloration, and diagnostic secondary compounds.

The final profile is taken from a peat face cut into a *Sphagnum fuscum* hummock on Reticulate Bog. The hummock surface was burned in a 1959 fire and the dead *Sphagnum fuscum* is covered by *Lecidea granulosa* and cup and horn lichens (*Cladonia coccifera, C. sulphurina, C. gracilis* and *C. chlorophaea*). Long, narrow frost cracks incise the surface of the hummock, and some slumping of the marginal portions of the hummock has occurred. The entire profile is composed of *Sphagnum fuscum* peat differentiated into dark humified portions and light well-preserved areas. The surface peats are well humified and are connected to darker peats at depth by an irregular network of humified peat. The dark peat lies along the frost cracks, which enable the penetration of oxygen to enhance decomposition in comparison to the lighter peats, which are retained in a relatively anaerobic environment.

DISCUSSION

A zonation of mires and mire surface patterns has been observed throughout the northern hemisphere (Osvald 1925, 1929; Paasio 1939; Sjörs 1983; Zoltai & Pollett 1983). In relatively flat regions such as Finland, where orographic effects are slight, the zonation is mainly latitudinal (Ruuhijärvi 1960; Eurola 1962). On larger land masses and where there is significant relief, an east–west or oceanic–continental patterns is often apparent (Dierssen & Dierssen 1978; Botch & Masing 1979; Damman 1979a; Kivinen & Pakarinen 1981; Vorren 1983). In south-eastern Labrador, the zonation of raised bogs and patterned fens is pronounced along an altitudinal gradient from the coast inland, although a significant latitudinal component is also observed.

The majority of discussions concerning mire zonation recognize the relationship between the zone boundaries and climatic indices such as effective temperature sum (Kivinen & Pakarinen 1981), evapotranspiration (Eurola & Kaakinen 1979; Eurola & Vorren 1980), and precipitation–evaporation quotients (Dierssen & Dierssen 1978), or correspondence with known phytogeographic zones (Botch & Masing 1979). The hypothesis that best describes the effect of climate on mire development and distribution in south-eastern Labrador invokes the role of moisture surplus and the effect of soligenous water flow (cf. Damman 1979a, b; Sjörs 1983).

The raised bogs of Labrador are restricted to a coastal zone, where the climate is influenced by maritime air masses and is characterized by more equable temperatures, less precipitation and less snowfall than occurs inland. Inland the greater moisture surplus results from increased precipitation and decreased temperature, which has a strong correlation with evapotranspiration (Thornthwaite 1948). Both in the interior and at higher latitudes, the amount of run-off is great, especially during spring snow melt. The effect of minerogenic water-flow is to promote decomposition and inhibit the accumulation of peat above the anaerobic water table (cf. Clymo 1983). As the flow of mineral-rich water increases there is a reduction in raised-mire development and an increase in minerotrophic mires. Within the patterned fen zone, raised mires become increasingly restricted to physiographic sites located away from the influence of mineral-rich water (cf. Kulczynski 1947). Such sites include water divides, river banks, lake shores, and extremely coarse, well-drained soils (Sjörs 1948; Ruuhijärvi 1970).

The controlling influence of soligenous water flow on mire development in south-eastern

Labrador is most apparent in the transitional area between the zones of raised bogs and patterned fens. For example, at Ranger Mire, the bog occupies a slight rise away from the direct influence of the minerotrophic waters that feed the fen seepage-ways. Under the influence of soligenous water the peat does not accumulate much above the anaerobic horizon, whereas, in the ombrotrophic portion of the mire, the peat accumulates to a much greater depth and rises above the surrounding mineral uplands.

In the transitional zone in south-eastern Labrador, physiography exerts a controlling influence on mire development, as seen in a comparison of the St Lewis and Eagle plains. Although occurring at the same altitude and characterized by a similar climate, the St Lewis plain supports large plateau bogs and transitional mire complexes, whereas the Eagle plain contains predominantly minerotrophic mires. The St Lewis plain is relatively flat; water divides are occupied by raised bogs, whereas fens are located along streams and in seepage-ways. In contrast, the Eagle plain is weakly drumlinized, and run-off is focused through inter-drumlin swales that are occupied by strongly patterned fens.

Within the transitional mire complexes, the separation between bog and fen areas (mineral–soil–water limit *sensu* Thunmark (1940)) appears to be reasonably distinct, as recognized on the basis of landform characteristics, water chemistry, and floristics. At Ranger Mire there is good correlation between the pH, nutrient concentration, and flora, with pools of low pH and low nutrient concentration lacking minerotrophic plant indicators. Within the minerotrophic portion of the mire the water is funnelled along seepages in which linear pools have developed and the ridges, which are raised only slightly above the water table, are dominated by sedges and nutrient-'demanding' species of *Sphagnum*. In contrast, the bog pools are irregular in shape and are separated by broad, high peat hummocks covered by extensive lichens and *S. fuscum*. Only along deep pools, where the water extends to or near the mineral substratum and thereby allows the incursion of nutrient-rich water, is the separation between bog and fen difficult. These 'fen windows' (Du Rietz 1950) may occur throughout the bog and, although affecting the local environment of the pool, do not extend in influence beyond the pool margin.

Dynamics of the surface vegetation and formation of recurrence surfaces

As documented in shallow peat cores and monoliths, the surface vegetation on the raised bogs is quite dynamic. On peat hummocks the relative position and proportion of the *Sphagnum fuscum* and *Cladonia* spp. (primarily *C. stellaris* and to a lesser extent *C. rangiferina*) have varied repeatedly in the recent past. In hollows there are similar indications that carpet-forming *Sphagnum* species have overgrown mud bottoms, and the spatial arrangement of hydrophytic and mesic species has varied (Foster 1984a).

On raised-bog hummocks the process of *Cladonia* spp. overgrowing *Sphagnum*, followed by a resurgence of *Sphagnum*, produces a distinctive stratigraphy. Starting at depth, well-preserved *Sphagnum* grades into dark, humified *Sphagnum* underlying *Cladonia* remains. The *Sphagnum* that overtops the lichen grows and accumulates rapidly, producing fresh, well-preserved peat in a typical recurrence surface. The lichen remains decay much more rapidly than moss, and the resulting stratigraphy presents a sharp contrast between alternating bands of dark and light *Sphagnum* peat that are very similar in appearance to those found at depth throughout the peat long cores. The *Cladonia* spp., which form a distinct layer in surface peats, decompose and are compacted at depth. The deepest collection of lichen remains from beneath a recurrence surface in south-eastern Labrador is approximately 50 cm, and the material was nearly unrecognizable. Similar lichen dynamics have been observed throughout northern Europe (Du Rietz 1950; Tolonen 1966, 1980; Masing 1982) and elsewhere in Canada (Auer 1933; Pakarinen 1974).

Recurrence surfaces of light peat overlying dark peat have been reported extensively from Europe (Aartolahti 1967; Dickinson 1975; Barber 1981) and North America (Osvald 1929; Wenner 1947). This stratigraphy is very important in the interpretation of mire development, as it is believed to represent periods of slow peat accumulation followed by periods of more rapid accumulation under the control of the regional climate.

Wenner (1947), observing increases in *Cladonia* spp. and shrub cover on Labrador bogs and the stratigraphic occurrence of dark humification bands, suggested that the vegetation dynamics indicate recent changes in climate towards drier and warmer conditions. This interpretation lies within the tradition of modern European mire ecologists who, viewing raised bogs as in equilibrium with the climate, have been able to make close correlations between recurrence surface stratigraphy and climatic history (Tolonen 1966; Aartolahti 1967; Aaby 1978). This view is carried to the extreme by Barber (1981), who feels that even very small-scale features of bog stratigraphy are under climatic control.

Despite the overriding control of climate on bog development and peat stratigraphy it is apparent from the present study that local factors may produce very similar changes in the vegetation and thereby confound the stratigraphic interpretation. These factors include fire and changes in the water table resulting from mire development and pool formation. Fire tends to increase the cover of xerophytic lichens at the expense of the mesic bryophytes (Pakarinen 1974; Damman 1977). The death and replacement of the *Sphagnum* cover on hummock by lichens, followed by re-expansion of *Sphagnum*, will produce a recurrence surface. Although charcoal was found beneath some recurrence surfaces, the small amounts of charcoal produced by most fires makes it unlikely that the local cause of humification bands will always be detectable.

The dynamic enlargement, coalescence, and drainage of the open-water pools on raised bogs may produce significant changes in the degree of humification of the peats in neighbouring areas. The large pools are secondary features that have developed through differential peat accumulation on an undulating mire surface, progressive swamping of the adjacent vegetation, and gradual coalescence of adjoining pools (cf. Lundqvist 1951; Boatman, Goode & Hulme 1981; Ivanov 1981; Foster *et al.* 1983; Foster & King 1984). Evidence for this process includes the irregular shape of many pools, which suggests the fusion of smaller hollows, rows of peat and sedge islands that mark the position of degraded ridges separating pools, active erosion and decomposition of pool margins and bottoms, and erosion of peat by rivulets between pools. These observations are supported by field studies and photographic evidence from north-European raised bogs (Boatman 1972; Korchunov, Kusmin & Ivanov 1980; Mets 1982; Masing 1982) and Canadian mires (Auer 1933; Sjörs 1961b; Vitt, Achuff & Andrus 1975).

The factors affecting the development of the mires and their vegetation dynamics are very different in nature and in scale. On a regional scale the distribution and zonation of the mires are largely controlled by the regional climate as influenced by such local factors as physiography, soils and exposure. Although climate controls the overall development of the mires, other factors including fire and pool drainage may produce confounding vegetational and stratigraphic changes. Whereas fire and climate operate extrinsically on mires, the pool enlargement, coalescence and drainage appear to be intrinsic processes of mire development. Recognition of the various factors and the scales on which they operate will lead to an understanding of the modern vegetational pattern and to the elucidation of the stratigraphic relations.

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