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Stratigraphy and Pollen Flora of some Bogs of the North Pacific Coast of America.

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Introduction.

In 1927 the writer had the opportunity of visiting during a fortnight a number of bogs (mosses) in the Fraser River delta and surrounding districts, i. e. the comparatively small ones South Port Mann bog, Cloverdale bog, Custer bog, the vaste areas Great Delta bog, Lulu Island bog and Tyne Head bog, all on the main land (see fig. 1), and Tyee bog on Vancouver Island. An account of the work on these bogs and their vegetation is given in a previous paper (Osvald 1933). The purpose of the present paper is to describe the stratigraphy of some of the bogs and to report on the results of the pollen analyses of the peat samples collected in some of the profiles.

The borings were made with the ordinary Swedish peat borer (Hillers peat auger) 9 m in length and with 50 cm sampler. The degree of decomposition is given in symbols H = 1 to H = 10 according to the von Post scale, where H = 1 means practically undecomposed peat, H = 10 completely decomposed peat. The pollen analyses were made at Växtbiologiska institutionen (The Plant Biological Institution) of the University at Uppsala by Mr. Carl Larsson, to whom I want to express my sincere thanks for valuable assistance.

The most detailed studies were made at the South Port Mann bog and at the Lulu Island bog.

South Port Mann bog.

South Port Mann bog is situated in a depression in the moraine south of New Westminster. It is a raised bog, although the features of this bog type are not very conspicuous, the lagg being poorly developed with a *Spiraea* thicket as the dominant plant community; the central part of the area is practically treeless and covered with *Ledum* communities, mainly the *Ledum groenlandicum-Cladonia*-soc. For further information about the vegetation cfr. Osvald 1933.

The section was run from a small cultivated area in the lagg at the northern edge, across the center of the bog to the lagg at the south end of the bog, and comprises altogether 8 borings.

Boring 1. In the cultivated part of the lagg close to the uncultivated bog area.

50 cm *Carex* peat, H = 8.
The auger in sand.

Boring 2. Burned area in *Ledum* community.

a) 140 cm *Sphagnum fuscum* peat, H = 1, in the lower part mixed with some *Sphagnum magellanicum.*
b) 65 cm *Sphagnum* peat, H = 8, and wood moss peat, H = 9, alternating; the lower part changing into wood fen peat. At 1.60 m below the surface a thin layer of charcoal. At 1.75 m a stump.
c) 60 cm lake mud, grayish brown.
d) 15 cm wood peat, dark brown, H = 9, in the upper part with charcoal.
e) 20 cm *Sphagnum* peat, H = 6.
f) 5 cm *Carex* peat, black.
g) 5 cm clayey lake mud.
h) 10 cm grayish green sandy clay with debris of *Carex* (leaves and fruits), fruits of *Potamogeton*, two different species, some wood and rather much coniferous pollen. Ash content 93.52 %.
The auger in clay.

Boring 3. Burned area in *Ledum* community with a large number of dead specimens of *Pinus contorta.*

a) 165 cm *Sphagnum fuscum* peat (lower 15 cm with much *S. magellanicum),* H = 1—3.
b) 55 cm wood moss peat, H = 8—9, with rather much wood, and shrub moss peat, H = 6.
c) 10 cm muddy *Carex* peat, H = 8.
d) 50 cm grayish brown lake mud (= gyttja).
e) 45 cm grayish brown muddy *Carex* peat, H = 6—8 with much *Pinnularia* and spongie needles.
f) 85 cm grayish brown *Carex* peat, H = 6(—4), in the lower part with decreasing humification and increasing content of *Carex* radicels and *Sphagnum* debris.
g) 100 cm *Sphagnum-Carex* peat, H = 7—8, with wood debris, leaf sheats and radicels of *Carex, Sphagnum* leaves, *Menyanthes* seeds, very numerous pollen grains (alder) and rather much spongie needles. Ash content 9,68 %.
h) 50 cm lake mud (detritus-gyttja) with rhizoms and other debris of *Carex, Sphagnum* leaves, fruits of *Nuphar, Carex* and *Potamogeton,* a very great number of coniferous pollen grains, diatoms, desmids and spongie needles. Ash content 32,50 %.
The auger in sandy clay.

Boring 4. *Ledum* community with some low specimens of *Pinus contorta.* Close to the boring place a *Nymphaea* hollow.

a) 190 cm *Sphagnum fuscum* peat, H = 1—2, with some fibres of *Eriophorum vaginatum.* Ash content 7,91 % at 50—100 cm depth.
b) 50 cm *Sphagnum* peat, H = 8—9, with very much pollen grains of deciduous trees, fern spores, *Menyanthes* seeds, and *Cenococcum.* Ash content 7,47 % (200—240 cm).
c) 30 cm wood moss peat, H = 9, with shrub debris, wood and bark pieces. Ash content 3,54—3,68 %.

d) 30 cm *Sphagnum* peat, H = 6, with very much wood debris (mostly needles). Ash content 3,73 %.
e) 20 cm *Sphagnum* peat, H = 4.
f) 15 cm *Sphagnum* peat, H = 8.
g) 15 cm *Sphagnum* peat, H = 2.
h) 15 cm *Sphagnum* peat, H = 6.
i) 10 cm *Carex-Sphagnum* peat, H = 8.
j) 100 cm *Sphagnum* peat, H = 6—8, with some wood and shrub debris and *Eriophorum vaginatum* fruits. Ash content 8,30 %.
k) 45 cm *Carex* peat, H = 5, with rather much *Sphagnum,* some *Carex* fruits and rhizoms. Ash content 3,30 %.

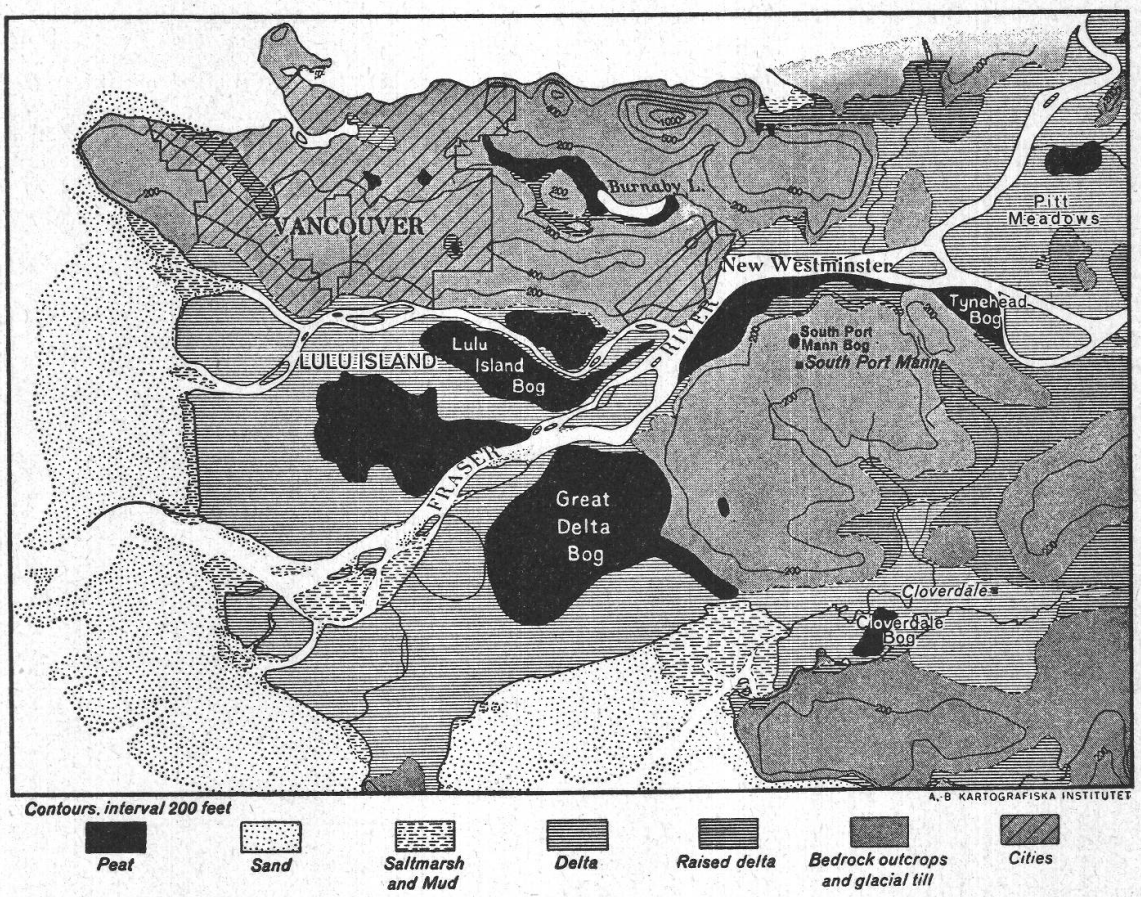

Fig. 1.
Situation of bogs in the Fraser River valley.

l) 85 cm *Carex* peat, H = 8, with wood and shrub debris. Ash content 4,98 %.
m) 95 cm lake mud (« detritus-gyttja ») in the lower part clayey, with some *Sphagnum* and wood debris, *Carex* fruits and radicels, *Nymphaea* fruits. Ash content 9,32 % (upper part) —12,96 % (lower part).
The auger in sand.

B o r i n g 5. Area with *Ledum-Cladonia*-soc. between small groups of pine and hemlock.

a) 175 cm *Sphagnum fuscum* peat, H = 1—2.
b) 10 cm *Sphagnum* peat, H = 8.

c) 80 cm wood moss peat, H = 9, in the upper part with a thin layer of charcoal, in the lower part with some *Carex*.
d) 75 cm brown lake mud with wood and *Carex* debris, some clay and sand, rather much diatoms *(Pinnularia)*. Ash content 29,58 %.
e) 95 cm wood fen peat, H = 8, in the upper part with a layer of 10 cm *Carex-Sphagnum* peat, in the lower part with much *Menyanthes* seeds. In the upper part a stump, at many niveaus thin layers of charcoal; contains *Carex* and *Sphagnum* debris, *Carex* fruits and *Cenococcum*. Ash content in the burned part 10,80 %, in the lower part 6,21 %.
f) 15 cm shrub fen peat with much *Oxycoccus,* some *Carex* and *Sphagnum*.
g) 45 cm *Carex* peat, in the upper part with much shrub debris; contains a large number of grayish brown, dark gray and, grayish yellow mycelium fibres; numerous *Menyanthes* seeds. Ash content in the upper part 5,98 %, in the middle 11,11 %, in the lower part 3,84 %.
h) 30 cm lake mud (« detritus-gyttja ») , very similar to wood fen peat, with *Menyanthes, Potamogeton* and *Nuphar* seeds. Ash content 10,99 %.
i) 5 cm grayish yellow lake mud (« plankton-gyttja »).
j) 15 cm clay.
The auger in sand.

B o r i n g 6. Area with *Ledum*-sociations with *Cladonia* and *Sphagnum* and with numerous small groups and single specimens of *Pinus contorta*.

a) 140 cm *Sphagnum fuscum* peat, H = 1—2.
b) 5 cm *Sphagnum cuspidatum* peat, H = 8.
c) 15 cm *Sphagnum fuscum* peat H = 8.
d) 90 cm wood fen peat, black, partly burned, and wood moss peat, H = 8—9, with much *Cenococcum,* in the lower part muddy and clayey.
The auger in sand.

B o r i n g 7. *Ledum-Hylocomium*-soc. in the marginal wood of pine and spruce.

a) 70 cm *Sphagnum fuscum* peat, H = 1—2.
b) 40 cm wood moss peat with much shrub debris.
The auger in sand.

B o r i n g 8. The margin of the bog.

40 cm wood moss peat.

A simplified diagram of the section through the South Port Mann bog is given in fig. 2.

The geological history of the bog may be summarized as follows. During the first stage (after the recession of the last ice sheet or since the area was lifted above sea level) the basin was an open lake, in which some clay and a rather thick layer of lake mud were sedimented. Later the open lake was overgrown by a *Carex* fen. In the northern part the *Carex* swamp continued to grow for a long time but at last it was invaded by a *Sphagnum* mat and some trees. In the southern part this invasion seems to have taken place much earlier, and here the wood swamp formed a thick layer of peat. Then the wood was flooded in both ends of the section — and probably all around the basin —

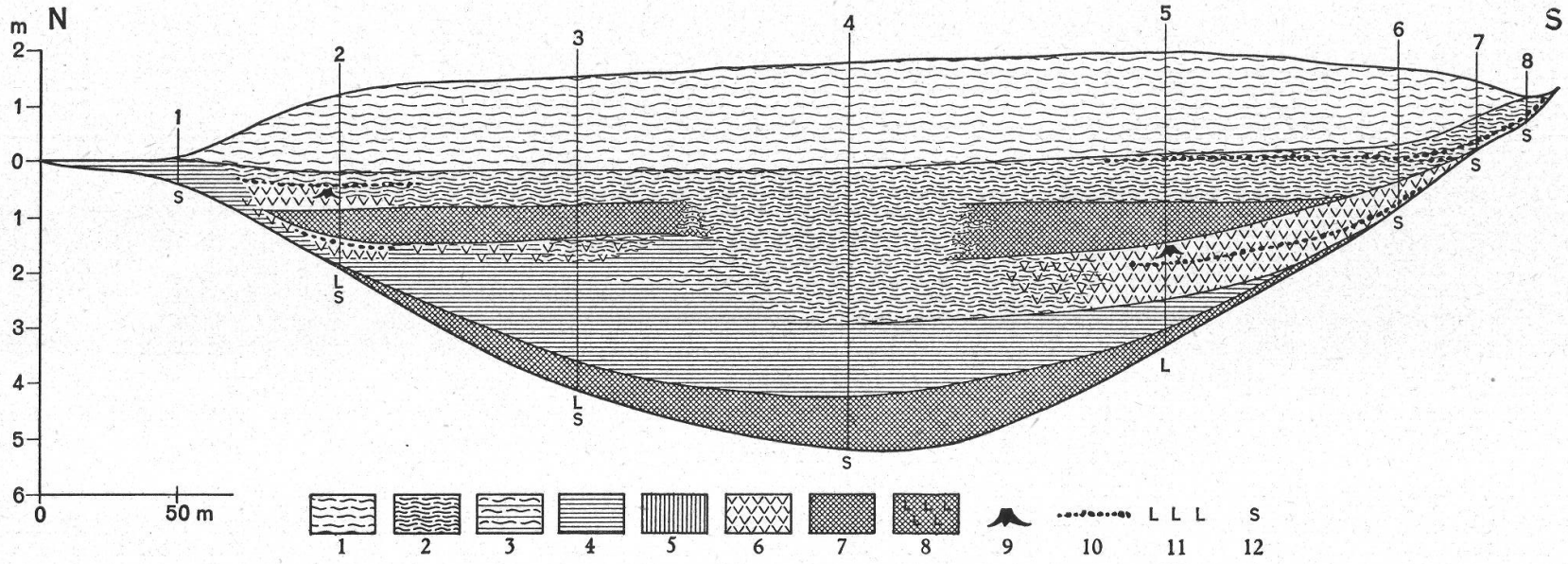

Fig. 2.

Diagram of the section through the South Port Mann bog. — Legend: 1. *Sphagnum* peat, H = 1—4. 2. *Sphagnum* peat, H = 5—10, and wood moss peat. 3. *Carex-Sphagnum* peat. 4. *Carex* (sedge fen) peat. 5. *Equisetum* peat and *Carex* peat with much *Equisetum*. 6. Wood fen peat. 7. Lake mud. 8. Lake mud with clay. 9. Stump. 10. Charcoal layer. 11. Clay. 12. Sand.

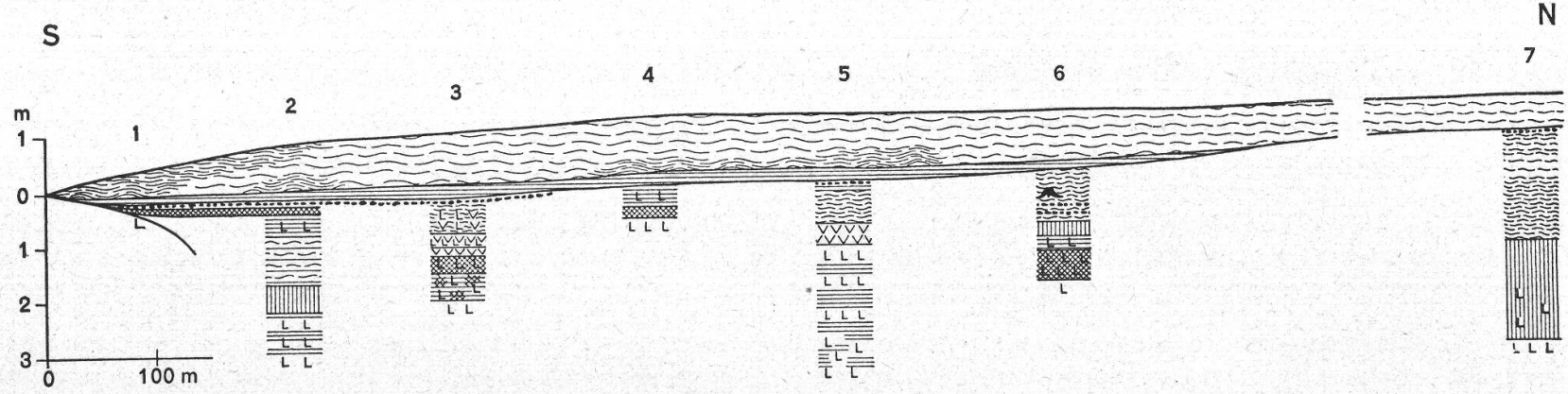

Fig. 3.

Diagram of the section through the Lulu Island bog. Because of the very irregular stratigraphy in the deeper parts of the bog, it has not been possible to connect the layers in the different profiles. For legend see fig. 2.

but in the center the *Sphagnum* mat was growing continuously. For a rather long time there seems to have been a *Sphagnum* island in a shallow lake surrounded by a wet wood. During the next stage the *Sphagnum* island spread over the surrounding open water, and for some time a well decomposed *Sphagnum* peat was formed, indicating that the *Sphagnum* bog was growing very slowly. At the end of this stage the bog was dry enough to burn. Then suddenly the well decomposed *Sphagnum* peat is followed by a nearly undecomposed one, which is still formed.

With the exception of the lake mud layer in the middle of the peat the general features of the stratigraphy are very similar to those of raised bogs in Europe and in other parts of North America. Consequently, it seems very likely that the sharp limit between the two *Sphagnum* layers corresponds to the subboreal-subatlantic contact in European bogs.

Further it seems to be an obvious conclusion, that the lake mud between the peat layers should indicate a climatic change. However, the flooding may be due to some local factors.

Custer bog.

Custer bog is situated in the north western part of the State of Washington in Whatcom County, only a short distance south of the International Boundary. The area is about 150 ha (R i g g 1922). The main part of the bog is covered with *Ledum* communities. On the north-eastern part, where the boring was made, *Pinus contorta* is common, forming rather dense groups. The following profile was found :

a) 160 cm *Sphagnum fuscum* and *S. magellanicum* peat, H = 2—4; roots of *Eriophorum vaginatum* and small shrubs. Ash content 4,74 %.

b) 155 cm wood moss peat and *Sphagnum* peat, mostly well decomposed, with much wood and spruce needles; ash content in the upper part 11,19 %, in the lower part 4,31 %.

c) 115 cm shrub moss peat, H = 5 (3—8), with very much rootlets, *Sphagnum* and some *Oxycoccus. Cenococcum.* Ash content 7,35 %.

d) 170 cm *Carex-Sphagnum* peat, H = 7, some radicels and mosses, wery much tree pollen, diatoms, desmids and spongie needles, fruits of birch, *Nymphaea* and *Carex,* spruce needles, wood etc. Ash content in the upper part 15,97 %, in the lower one 33,54 %.

e) 60 cm muddy *Carex* peat with about the same content as the previous layer.

f) 50 cm olive green lake mud (« plankton-gyttja »), with some layers of white sand, containing *Carex, Sphagnum,* mosses, diatoms, *Nymphaea* etc. Ash content in the upper part 63,05 %, in the lower part 74,08 %.

g) 65 cm dark brown lake mud with less diatoms than in the previous layer. Ash content 46,27 %.

h) 35 cm black lake mud, rather poor in diatoms, some *Nymphaea* fruits. Ash content 59,58 %.
At 8,10 the auger in clay.

This profile is very similar to the profile from the central part of South Port Mann bog.

The contact between the well decomposed wood moss peat and the nearly undecomposed *Sphagnum* peat is very conspicuous. It may be synchronous with the contact in the South Port Mann bog. It is hard to say, how the lower part of the profile should be interpreted, but the striking changes in the lake mud may indicate climatic changes during the early stages, when the basin was occupied by an open lake.

Tyne head bog.

Tyne head bog is located along the Fraser River, see fig. 1. The vegetation is composed mainly of *Ledum-Sphagnumangustifolium*-soc.,

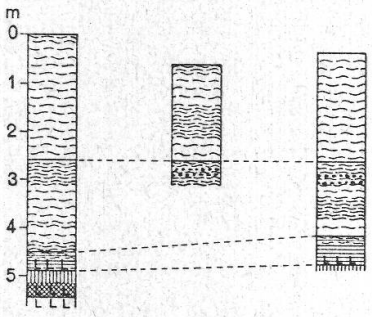

Fig. 4.
Diagram of the three profiles from the Tyne Head bog. For legend see fig. 2.

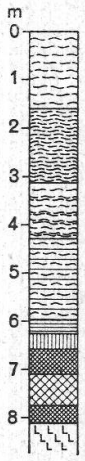

Fig. 5.
Diagram of one of the profiles from the Great Delta bog. For legend see fig. 2.

alternating with *Rhynchospora* depressions. *Pinus contorta* is growing in single specimens all over the bog. Three profile borings were made (see fig. 4).

B o r i n g 1. In the center of the bog.

a) 260 cm *Sphagnum fuscum* peat, H = 1—3.
b) 50 cm wood moss peat and *Sphagnum* peat, H = 5—9.
c) 140 cm *Sphagnum* peat, H = 2—5.
d) 20 cm *Carex-Sphagnum* peat with *Oxycoccus*, H = 5.
e) 20 cm *Carex* peat with thin layers of clay.
f) 55 cm clayey *Equisetum* peat.
At 5,45 the auger in clay.

B o r i n g 3. Between the railway and the mineral ground.

a) 225 cm *Sphagnum fuscum* peat, H = 1—2.
b) 25 cm *Sphagnum* peat, H = 5.
c) 20 cm wood moss peat, H = 10, with much charcoal.

d) 105 cm *Sphagnum* peat, H = 3—6.
e) 63 cm *Carex-Sphagnum* peat and *Carex* peat, H = 4—6.
f) 2 cm clay.
g) 10 cm *Equisetum* peat.

Boring 2 was made near the river. The stratigraphy down to 2,5 m was the same as in boring 3 with the exception that the slightly decomposed upper *Sphagnum* peat was 200 cm instead of 225 cm.

Also in this bog we find a very conspicuous contact between the well decomposed wood moss and *Sphagnum* peat and the nearly undecomposed *Sphagnum* peat. In two of the profiles much charcoal was found in the upper part of the wood moss peat. Clay layers were found in the lower parts of the profiles. This feature is still more characteristic in the profiles from Lulu Island bog and Great Delta bog.

Lulu Island bog.

Lulu Island bog is situated in the northwestern part of Lulu Island, along one of the delta branches of Fraser River. When the shallow peat soils all over the island were reclaimed, this comparatively deep bog was left, and large parts of it still remain in a rather natural stage, cut only by some great ditches. The vegetation of the relatively undisturbed areas consists for the most part of *Ledum* communities, either bare or with a bottom layer of *Cladonia, Pleurozia* or other mosses. Scattered in the fairly even surface several *Nymphaea* hollows are found (O s v a l d 1933). Over the whole area isolated specimens or small groups of *Pinus contorta, Tsuga heterophylla* and *Thuja plicata* are growing. To the north (i. e. nearer the river) the bog passes into a fairly open wood fen, and this in its turn into a sedge fen.

A profile was run from a point at road 8 at the southern margin of the bog in the direction N 30° E. The vegetation of the bog margin, which was strongly influenced by reclamation work, was a mosaic of *Carex vesicaria* fen and *Ledum* communities with scattered pines.

B o r i n g 1. Bare *Ledum*-soc. near a group of pines and a *Nymphaea* hollow.

a) 50 cm *Sphagnum* peat, H = 7, black.
b) 10 cm *Carex-Sphagnum* peat, H = 7.
c) 10 cm wood moss peat, H = 9, with charcoal.
d) 5 cm lake mud.
The auger in clay.

B o r i n g 2. *Ledum* communities, bare and with *Cladonia;* some *Sphagnum fuscum* hummocks.

a) 80 cm *Sphagnum fuscum* peat, H = 2, in a 10 cm layer H = 5.
b) 15 cm *Carex-Sphagnum* peat, H = 8.
c) 10 cm wood fen peat and *Carex* peat, H = 9.

d) 15 cm clayey lake mud.
e) 30 cm clayey *Carex* peat.
f) 100 cm *Carex-Sphagnum* peat, H = 8.
g) 60 cm *Carex* peat, H = 8, in the lower part clayey and muddy and with much *Equisetum.*
h) 25 cm clay with *Carex* and wood debris.
i) 15 cm clayey *Carex* peat.
j) 10 cm clay.
k) 15 cm clayey *Carex* peat with *Equisetum.* Clay with wood and *Carex* debris.

Boring 3. Burned area.

a) 90 cm *Sphagnum fuscum* peat, H = 2.
b) 20 cm *Sphagnum* peat with *Carex,* H = 6.
c) 10 cm *Sphagnum* peat, H = 8.
d) 20 cm wood moss peat, H = 9, with charcoal in the upper part, clay in the lower part.
e) 20 cm wood fen peat.
f) 20 cm wood moss peat, H = 8.
g) 40 cm wood fen peat, with clay layers.
h) 30 cm clay.
i) 50 cm clayey and muddy *Carex* peat.
Clay with *Equisetum* rhizoms.

Boring 4. Bare *Ledum*-sociation.

a) 100 cm *Sphagnum fuscum* peat, H = 1—2.
b) 25 cm *Carex-Sphagnum* peat.
c) 45 cm *Carex* peat with clay and some wood.
d) 10 cm clayey lake mud.
Clay with *Carex* rhizoms.

Boring 5. Bare *Ledum*-sociation with scattered *Sphagnum fuscum* hummocks.

a) 100 cm *Sphagnum fuscum* and *Sphagnum cuspidatum* peat, H = 1—4, in the lower part with some *Carex* roots.
b) 35 cm *Carex* peat, with a layer of charcoal.
c) 65 cm *Sphagnum* peat, H = 8, and wood moss peat, H = 9.
d) 35 cm wood fen peat with some *Equisetum.*
e) 40 cm clay with *Equisetum* rhizoms.
f) 15 cm clayey *Carex* peat.
g) 35 cm clay with some *Carex.*
h) 25 cm clayey *Carex* peat.
i) 30 cm clay with some *Carex.*
j) 20 cm clayey *Carex* peat.
Clay with *Carex* debris.

Boring 6. Mosaic of *Ledum* communities, bare and with *Sphagnum.*

a) 90 cm *Sphagnum fuscum* peat, H = 2—3.
b) 10 cm *Carex* peat, H = 7, black.
c) 35 cm *Sphagnum* peat, H = 7—5.
d) 65 cm wood moss peat, H = 8—6. At 1,5 m depth a stump; below the stump several horizons with charcoal.
e) 50 cm *Carex* peat with *Equisetum,* in the lower part clayey.
f) 50 cm clayey lake mud with *Carex* and *Equisetum.*
Clay with wood debris.

Boring 7. About 300 m from the northern margin of the bog.

a) 60 cm *Sphagnum fuscum* peat, H = 1.
b) 10 cm wood moss peat, H = 9, with charcoal.
c) 30 cm *Sphagnum* peat, H = 2—4.
d) 15 cm *Sphagnum fuscum* peat, H = 7.
e) 35 cm *Sphagnum fuscum* peat, H = 2.
f) 110 cm *Sphagnum* peat, H = 6—8.
g) 190 cm muddy and clayey *Carex* peat, with much *Equisetum*. Clay.

In fig. 3 I have tried to draw a diagram of the section through the bog. In the early stages the succession is a rather complicated one, and it isn't possible to correlate the layers in the different profiles. The area has evidently for long periods been a complex of swampy woods, sedge fens and open water. At intervals it has been flooded, which is indicated by the alternating layers of peat and clay, and by the high clay content in many of the peat layers. Not until rather late the bog seems to have been established as a complex of moss forest and open moss and fen areas. I am inclined to think that this stage corresponds to the upper part of the wood moss stage in the South Port Mann bog. A the end of this stage the area burned off, and then an open *Carex* fen invaded the main part of the bog. But it didn't last very long, until this fen stage was replaced by the *Ledum-Sphagnum fuscum* bog stage. which, is represented in the profile by the undecomposed *Sphagnum fuscum* peat. The very conspicuous contact, which was easily observed in a great ditch along the profile, between the *Carex* peat and the underlying peat probably indicates a change in the climate.

The Great Delta bog.

The Great Delta bog is the largest of the large bogs in the Delta land. It has, however, been very much influenced by reclamation work. Roads run across the bog, ditches are cut through it and so on. From this bog I didn't get more than two profiles, one rather deep and one shallow. The general character of the profile is very similar to those of Lulu Island as will be seen from the following notes (see also fig. 5):

a) 15 cm shrub moss peat, H = 8.
b) 55 cm *Sphagnum fuscum* peat, H = 1—2.
c) 35 cm shrub moss peat, H = 7.
d) 35 cm *Sphagnum fuscum* peat, H = 3.
e) 10 cm *Sphagnum cuspidatum* peat, H = 8.
f) 15 cm *Sphagnum fuscum* peat, H = 5.
g) 40 cm shrub moss peat, H = 8.
h) 50 cm wood moss peat, H = 7—9, with charcoal at different horizons.
i) 40 cm *Carex* peat, H = 6, in the lower part with much *Equisetum*.
k) 5 cm clay, grayish brown, with some *Equisetum* rootlets.
l) 20 cm clayey shrub moss peat, H = 7.
m) 10 cm muddy clay.

n) 20 cm shrub moss peat.
o) 20 cm clayey and muddy *Carex* peat.
p) 50 cm muddy clay with some *Carex* debris.
q) 25 cm clayey *Carex* peat.
r) 130 cm clay, grayish brown, with very much *Carex* debris.
Clay, bluish gray.

To judge from this profile the geological history of Great Delta bog has been about the same as that of Lulu Island bog.

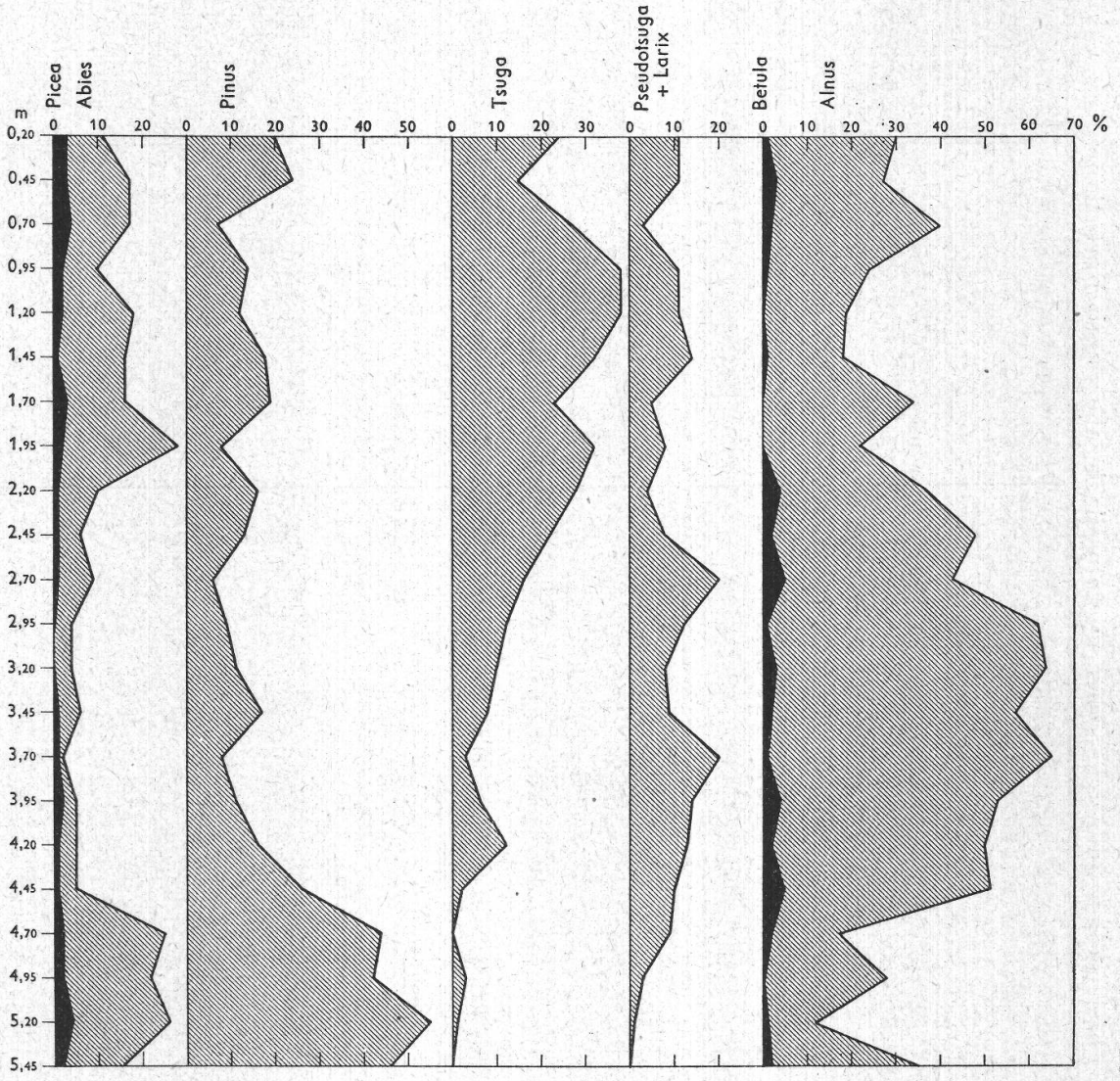

Fig. 6.
Pollen diagram from profil 3 of the South Port Mann bog.

Pollen analyses.

South Port Mann bog.

The pollen analyses from this bog was made on a series of samples from boring 3. The results are given in table 1 and 2 and in figure 6 and 7. It is easy to distinguish three very obvious periods or stages, viz.

Table 1.

Fossil pollen and some other microfossils in the South Port Mann bog.

Depth m	Sample number	Number of pollen grains counted	Percentage of recognised tree pollen							Number of unknown tree pollen				Other microfossils				
			Abies	*Picea*	*Pinus*	*Tsuga*	*Pseudotsuga* + *Larix*	*Betula*	*Alnus*	« *Sequoia* type »	« *Salix* type »	« *Quercus* type »	Other	*Nymphaea* pollen	*Pinnularia*	*Spongie* needles	*Assulina*	*Arcella*
0.25	145	135	11	3	20	24	11	1	30					1			1	×
0.50	146	101	17	3	24	15	11	3	27		1			1			1	×
0.75	147	122	17	4	7	27	3	2	40		1							
1.00	148	124	10	2	14	38	11	1	24									
1.25	149	105	18	2	12	38	11	—	19		3							
1.50	150	104	16	1	18	32	14	1	18		1		2		×		×	
1.75	151	118	16	3	19	23	5	—	34	1			1 [1]					
2.00	152	131	28	2	8	32	8	—	22									
2.25	153	137	10	1	16	28	4	4	37	2			2					
2.50	154	133	6	1	13	22	8	2	48				3 [2]					
2.75	155	137	9	1	6	16	20	5	43					1	×	1		
3.00	156	141	4	—	9	12	12	1	62	7				1	×	×		
3.25	157	103	4	—	11	10	8	3	64	1		2		2	×	×		
3.50	158	119	6	1	17	8	9	2	57			1						
3.75	159	117	2	1	8	3	20	1	65			1						
4.00	160	106	5	2	11	6	14	4	53		2		3			×		
4.25	161	125	5	1	16	12	13	2	50	2	1	1	1 [2]	1	1	×		
4.50	162	121	5	1	26	2	10	5	51	12						×		
4.75	163	119	25	2	44	—	9	2	17	2		1				×		
5.00	164	124	22	2	42	3	3	—	28	1				1				
5.25	165	138	26	4	55	1	1	1	12	1				1				
5.50	166	134	15	2	46	—	—	2	35	2			2	1	1	×		

[1] *Rhamnus ?* [2] *Corylus ?*

Table 2.

Fossil pollen in the Lulu Island bog.

Depth m	Sample number	Number of pollen grains counted	Percentage of recognised pollen							Number of unknown pollen				
			Abies	*Picea*	*Pinus*	*Tsuga*	*Pseudotsuga* + *Larix*	*Betula*	*Alnus*	« *Sequoia* type »	« *Salix* type »	« *Corylus* type »	« *Quercus* type »	Other
0.25	167	101	16	2	32	7	1	2	40					
0.50	168	121	10	2	21	14	4	3	46			1		
0.75	169	102	14	3	13	27	4	4	36	1				1
1.00	170	122	9	2	27	23	—	4	35			1		1
1.25	171	129	11	5	29	13	2	4	36					4
1.50	172	133	2	1	27	2	—	4	64	1	2			
1.75	173	121	10	3	36	12	3	5	22		1	1		
2.00	174	101	12	20	51	9	6	2	10				1	
2.25	175	124	12	5	27	14	1	2	39					9
2.50	176	102	19	4	18	21	3	5	30	1				
2.75	177	102	5	5	28	13	1	7	41		1	1		
3.00	178	112	11	13	28	8	1	2	37					
3.25	179	104	8	8	29	7	2	4	42		2			

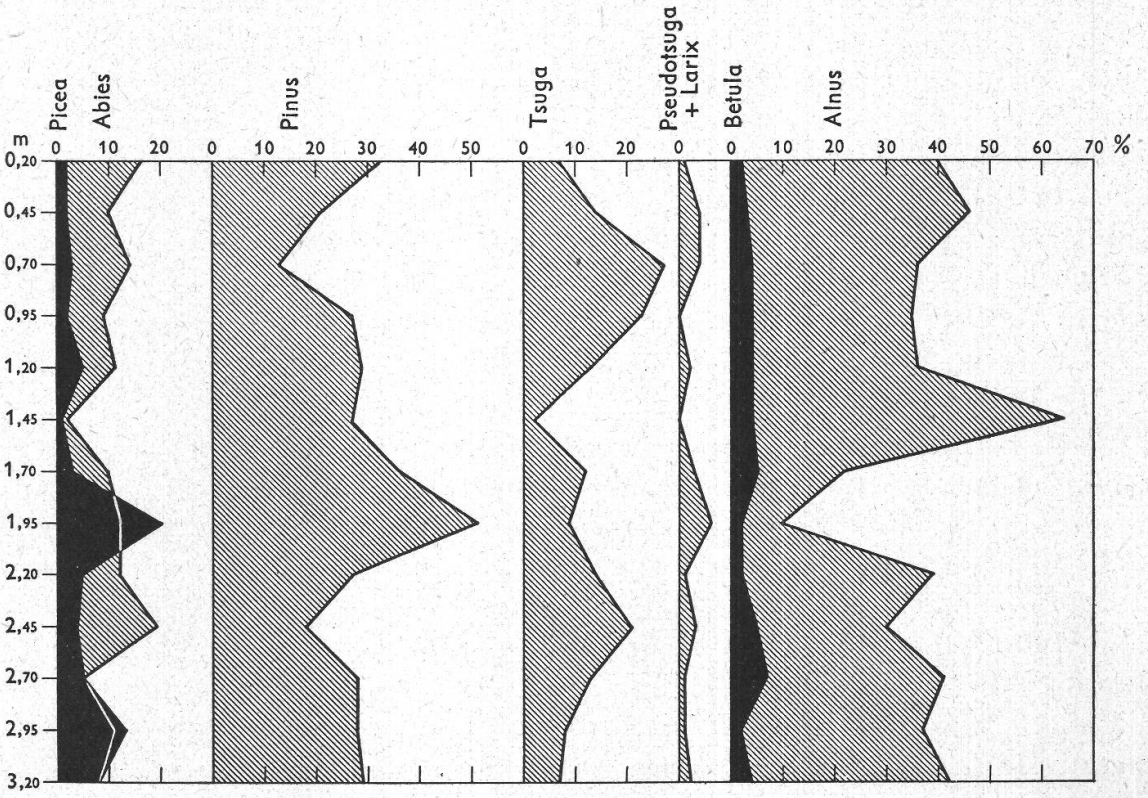

Fig. 7.

Pollen diagram from profile 4 of the Lulu Island bog.

1. The (northern) coniferous forest stage (samples 163—166). During this stage the northern coniferous elements, *Abies*, *Picea* and *Pinus*, probably formed the main part of the forest, their contribution to the pollen flora varying between 63 and 85 %. *Pinus* was the most prominent genus with *Abies* in the second place.

2. The deciduous forest (including *Tsuga* and *Pseudotsuga* + *Larix)* stage (samples 151—162). This stage is characterized by high or very high percentages for *Alnus*, in the lower 2/3 of the peat from this period rather high percentages for the group *Pseudotsuga* + *Larix*, increasing figures for *Tsuga*, and, excepting the last part, low percentages for the coniferous trees *Abies*, *Picea* and *Pinus*, among which *Pinus* is still the most important.

3. The mixed forest stage (samples 145—150). *Abies*, *Picea* and *Pinus* contribute to the pollen flora with about 35 % (26—44 %), *Abies* and *Pinus* being about equal. *Tsuga* plays a very important rôle particularly in the beginning of this period, about 30 % (with one exception 24—38 %). *Picea* shows still low, but obviously higher percentages than in most of the previous period. *Alnus* starts with a minimum during this period.

In the general appearance there is a rather good coincidence with the periods which have been pointed out by Fuller (1935), Houdek, Sears (1935) Voss, Osvald (1935) and others for other parts of the North American continent. There seems to be no doubt that at least some of these variations in the composition of the forests indicate climatic changes during the postglacial time, but owing to the small area of the bog, the local changes in the flora have played an important rôle. However, there doesn't seem to be much correspondence between the sequence of strata in the peat and the relative frequency of the forest trees. For instance the change in the profile between 1,50 and 1,75 m depth is not accompanied by any remarkable change in the pollen flora.

It seems to be possible to subdivide the second stage in three subdivisions, the first part (samples 159—162) being characterized by decreasing *Pinus*, increasing *Alnus* and *Pseudotsuga* + *Larix*, and mostly low figures for *Tsuga*, the second one by obviously increasing *Tsuga*, decreasing *Alnus*, and low figures for *Abies*, the third one by high figures for *Abies*, low figures for *Pseudotsuga* + *Larix*, relatively low for *Alnus*, and *Betula* disappearing. The second one of these subdivisions would correspond fairly well to the layer of a lake mud and muddy *Carex* peat in the profile.

Lulu Island bog.

The pollen diagram from Lulu Island bog doesn't seem to reach further back than to the second subdivision of the second stage in the South Port Mann bog diagram. The changes in the pollen flora are much more irregular than in the South Port Mann bog, and it is hardly possible to distinguish different periods. There is, however, some similarity between the two diagrams in the *Alnus* curve and the *Tsuga* curve during the third stage.

Discussion and summary.

In most of the profiles described in the present paper a layer of well perserved *Sphagnum fuscum* peat has been found overlying a well decomposed peat, either *Sphagnum* peat or wood moss peat. According to Rigg (1925) the same stratigraphy seems to be characteristic of a large number of bogs along the North Pacific coast of America. The contact between the two upper layers of the bogs is very similar to the subboreal-subatlantic contact in European bogs, and very likely indicates a change in the climatic conditions of the region. The pollen analyses show that the bogs in the delta land originated much later than the bogs on higher ground. Some of them do not seem to have become stabilized as bogs until shortly before the beginning of the last stage (the *Sphagnum fuscum* bog stage) in their development. Although there are rather great differences between the two pollen analyses, due probably to local influences in both of them, it is obvious that great changes in the composition of the forest vegetation of the region have taken place. It seems possible to distinguish three stages, viz.

1. The (northern) coniferous forest stage,
2. the deciduous forest (including *Tsuga* and *Pseudotsuga* + *Larix*) stage,
3. the mixed forest stage.

The change from stage 1 to stage 2 is the most striking one. The pollen flora suggests the possibility of subdividing stage 2 in three subdivisions.

Finally it should be emphasized that the correspondence between the stratigraphy and the changes in the pollen flora is not obvious. Moreover, it is rather difficult to interpret in detail the pollen diagram, since many of the figures comprise several species in each genus, and, consequently, the significance of the changes is perhaps not clear enough to be used for conclusions regarding the climate. Nevertheless, a period of increasing warmth seems fairly well marked in the decrease of the northern coniferous forest elements (*Abies, Picea* and *Pinus*) at the end of the first stage.

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