Pollen analysis of postglacial sediments from Eildun Lake, District of Mackenzie, N.W.T., Canada

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Sediment from Eildun Lake, located at 63°8.6'N, 122°46.5'W in the northern boreal forest, was cored to a depth of 268 cm and analyzed for pollen content. Pollen percentages and 14C dates suggest a vegetational sequence extending back over 11,000 years. The sequence begins with a discontinuous herb tundra dominated by Artemisia and Gramineae. This was succeeded by a shrub tundra dominated by dwarf birch and willow. Poplar had invaded by approximately 10,700 BP to form a dwarf birch - poplar grove land or forest tundra. Between approximately 10,300 and 7,510 BP spruce replaced poplar as the dominant tree, although still forming a forest tundra. Boreal forest, including tree birch and alder, became established shortly after 7,510 BP and has persisted since then with very little change. Pinus pollen has increased in percentage, particularly during the last 2400 years, reaching its Holocene maximum at the present day. The percentages attained indicate the presence of pine trees regionally though not in the near vicinity of Eildun Lake.

Les sédiments du Lac Eildun, localisé à 63°8.6'N, 122°46.5'O dans le secteur nord de la forêt boréale, ont été échantillonnés au moyen d'un carottier jusqu'à une profondeur de 268 cm et le contenu en pollens a été analysé. Les pourcentages en pollens et les datations au 14C révèlent une séquence végétale reculant jusqu'à 11,000 années. La base de la séquence représente une toundra d'herbacées dominée par Artemisia et des graminées. Par la suite on retrouve une toundra à bouissons dominée par des bouleaux et des saules rabougris. La prolifération du peuplier, il y a approximativement 10,700 années avant le présent, a développé un parc subarctique ou une toundra boisée. L’épinette a remplacé le peuplier durant l’intervalle approximatif de 10,300 à 7,510 années avant le présent pour devenir l’espèce dominante même si le milieu demeurait une toundra boisée. La forêt boréale, incluant les bouleaux et les aulnes, a pris place peu de temps après 7,500 années avant le présent, et depuis elle a été peu modifiée. Le pourcentage de pollen de Pinus s’est accru, particulièrement durant les dernières 2400 années, pour atteindre son maximum de l’Holocène à aujourd’hui. Les pourcentages établis indiquent la présence de pins à l’échelle régionale, mais ils sont absents dans les environs immédiats du lac Eildun.

[Traduit par le journal]


Introduction

In conjunction with the archaeological excavation of the Esker Bay site, KgRi-11 (Losey et al. 1979), pollen analysis was performed on a sediment core from a nearby small lake informally named Eildun Lake (Slater 1978) (Fig. 1). The purpose of this research was to develop a local palaeo-environmental sequence for correlation with cultural data from the multicomponent site and to contribute towards a general history of postglacial vegetation in northwestern North America. Of particular interest was the “ice-free corridor” in relation to cultural as well as zoological and botanical developments in the region.

Although not located directly within the area generally considered to form the northern portion of the ice-free corridor, Eildun Lake lies close to the eastern boundary of that area (Rutter 1980, p. 6). Early in the postglacial period, as a result, the lake vicinity would have been subject to colonization by both floral and faunal populations that inhabited that corridor. Pollen data from Eildun Lake are, therefore, of interest in determining the ecology of the northern ice-free corridor.

Ritchie (1977, p. 401) indicated that a necessary first step in addressing these larger problems of ecology lies in contributing basic vegetational history data with pollen diagrams, such as that offered here. The present study includes a radiocarbon-dated pollen sequence extending back into the late postglacial. Relatively few such data have been made available for this region.

The closest sites to Eildun Lake for which comparable data have been presented (Fig. 1) are John Klondike Bog (Matthews 1980), in the extreme southwestern corner of the District of Mackenzie, and Natla Bog (MacDonald 1983), in the central Selwyn Mountains ~300 km west of Eildun Lake. To the north, Ritchie’s (1977) M Lake data from the Inuvik area are the closest available for comparison. The nearest to the south are from Lighti-Federovich’s (1970) Lofty Lake study from central Alberta. Studies to the east are either from outside the forest altogether or not directly comparable with Mackenzie Valley vegetation history.

Environmental setting

The following summarizes the local and regional environmental setting of Eildun Lake. A more complete discussion is in Losey et al. (1979).

Physiography

Eildun Lake (Fig. 2) lies at an elevation of 302 m above mean sea level (msl). It has a surface area of approximately 50 ha and an average depth of 2–3 m. Several small, intermittent streams feed and drain the lake, which lies on a plateau approximately 15 km east of the Franklin Mountains. This plateau forms a part of the Interior Plains physiographic region, which is subdivided into the Great Bear Plain to the north and the Great Slave Plain to the south (Bostock 1970). Eildun Lake lies approximately on the boundary between these two regions.

The topography in the immediate vicinity of the lake has been modified by late Wisconsin glaciation, the chronology of which is poorly understood (Crampton 1973). The landscape varies from flat to rolling, with thick deposits of glacial till. Several drumlins, drumlinoid mounds, and eskers are locally present.
Climate
Throughout most of the year, including early summer, the prevailing regional winds are from the north and northwest. By mid-summer, southerly winds become dominant (Bryson and Hare 1974). This pattern is modified by the periodic accentuation, between early summer and early autumn, of southerly and easterly flows through the valley of River-Between-Two-Mountains and the basin of the eastern arm of Fish Lake. This “valley wind funnel effect” (McAndrews et al. 1979) may have affected pollen deposition in Eildun Lake in terms of long-distance transport of light, anemophilous pollen grains from these directions.
Mean daily temperatures range from $-28^\circ$C in January to 16$^\circ$C in July. The region has approximately 230 days/year with freezing temperatures. An average of 30 cm of precipitation falls each year, mostly as rain during June, July, and August, although snow commonly falls during all other months of the year (Dominion Bureau of Statistics 1974).

Soils

Dominant soil types in the Eildun Lake region consist of eutric brunisols in better drained areas and patches of cryic fribisol and mesisols in areas of greater soil moisture (Clayton et al. 1977; Tarnocai 1973). The soil climate is subarctic, with short periods of saturation and only slight seasonal moisture deficits.

The region is also characterized by discontinuous permafrost in which frozen and unfrozen patches of soil are interspersed (Tarnocai 1973). The thickness of the “active layer” above frozen patches may vary considerably over years in reaction to variations in climate and vegetation cover (e.g., Dingman and Koutz 1974).

Vegetation

Eildun Lake lies within the Northwestern Transition Section of the Boreal Forest region (Rowe 1972). Although portions of this broadly defined vegetation zone may be quite open, particularly in areas closer to the tundra 400–500 km to the northeast, the Eildun Lake region itself is densely forested. Major plant community characteristics particular to the immediate study area are given below. For a more detailed botanical description of this region see Porsild and Cody (1980).

Eildun Lake is surrounded by a black spruce (Picea mariana) – sphagnum moss (Sphagnum) bog that grades to black spruce – lichen (primarily Cladonia and Cetraria) forest on the upland. Tamarack (Larix laricina) is a minor tree. A sparse understory of alder (Alnus) and dwarf birch (Betula glandulosa) is present, along with a variety of feather mosses (e.g., Hylocomium) and heath plants (Ericaceae).

Several drumlinlike features rise 20–30 m above the level of the bog on the northeast side of the lake. Their summits are dominated by paper birch (Betula papyrifera) and trembling aspen (Populus tremuloides), although numerous small saplings of white spruce (Picea glauca) are present. The understory of this community is dominated by prickly rose (Rosa acicularis) and shrubby cinquefoil (Potentilla fruticosa).

A large esker just south of the lake is dominated on its north-facing slope by white spruce and a dense shrub cover of alder and willow (Salix); also present are numerous species of herbs (e.g., Cornus canadensis, Equisetum), lichens, and mosses. The summit and south-facing slope of the esker support a much more open stand of white spruce, paper birch, and juniper (Juniperus communis) as well as various grasses (Gramineae) and heath plants.

The better drained stretches of the shores of Fish Lake support stands of white spruce, paper birch, trembling aspen, and balsam poplar (Populus balsamifera) as well as soapberry (Shepherdia canadensis), prickly rose, heaths, grasses, and numerous other herbs. Jack pine (Pinus banksiana) is rare near Eildun Lake, although it is common adjacent to the Mackenzie River to the west and on better drained uplands to the southeast.

Methods

A core of sediment 268 cm long was recovered from Eildun Lake with a stationary piston sampler from beneath 230 cm of
TABLE 1. Radiocarbon ages of samples from the Eildon Lake core

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Material</th>
<th>Laboratory No.</th>
<th>$^14$C age (years BP)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>80–85</td>
<td>Gyttja</td>
<td>GSC-2749</td>
<td>2380 ± 100</td>
<td>Possibly too old</td>
</tr>
<tr>
<td>115–120</td>
<td>Gyttja</td>
<td>GSC-2753</td>
<td>4510 ± 110</td>
<td>Possibly too old because of old carbonates</td>
</tr>
<tr>
<td>150–160</td>
<td>Gyttja</td>
<td>TX-2919</td>
<td>7510 ± 120</td>
<td>Possibly too old because of old carbonates</td>
</tr>
<tr>
<td>165–170</td>
<td>Marl</td>
<td>GSC-2743</td>
<td>10300 ± 290</td>
<td>Rejected because of contamination with pre-Quaternary carbon</td>
</tr>
<tr>
<td>200–205</td>
<td>Marl</td>
<td>GSC-2737</td>
<td>10700 ± 290</td>
<td></td>
</tr>
<tr>
<td>242–247</td>
<td>Silty clay</td>
<td>GSC-2695</td>
<td>&gt; 30000</td>
<td></td>
</tr>
</tbody>
</table>

water. Sediment samples of 0.9 mL were taken at 2 cm intervals from the upper 238 cm of the core. The samples, after the addition of tablets containing a known number of *Lycopodium clavatum* spores, were treated with 10% HCl, hot 10% KOH (aqueous), hot HF, acetolysis solution, safranin staining, and tertiary butyl alcohol, then were mounted in silicon oil (2000 cSt (20 cm$^2$/s)). Samples from below 202 cm depth in the core were screened through a 7 μm mesh nylon screen to remove clay particles (Cwynar et al. 1979).

Pollen and spore totals for each level were expressed as a percentage of the pollen sum of over 400 grains per sample from trees, shrubs, and herbs, including Cyperaceae but excluding aquatics. At 20 cm intervals 100 *Betula* grains were measured to determine size frequency. The measurement used was the diameter, in polar view, from a pore annulus to the outer edge of the opposite side of the grain. These measurements are displayed as histograms for each relevant level in Fig. 3. The centre of the median class has been emphasized by a vertical line for ease of reference.

Fossil concentration per millilitre was calculated for each sample by the introduced spore method (Stockmarr 1972). Estimates of the amount of organic matter were calculated as percentage of dry weight loss on ignition (LOI) after heating the samples at 550°C for 4 h. Six levels were radiocarbon dated.

**Results**

**Sediment stratigraphy**

The lower 67 cm of the core consisted of a silty clay with thin lenses of sand near the bottom. This section represents proglacial lake sediments and the early stages of surface stabilization around the lake. The interval from 201 to 156 cm consisted of faintly laminated marl representing leaching of the stabilized surface by groundwater. The upper 156 cm consisted of gyttja deposited in water that was relatively carbonate free as a result of the earlier leaching process.

At 75 cm depth there was a 0.7 cm thick lens of volcanic ash. Volcanic ash layers are common in the soils of this region and are considered most likely to be White River ash derived from the Saint Elias Mountains in eastern Alaska. Microscopic examination of an ash sample from the Eildon Lake core revealed it to be mineralogically consistent with White River ash (J. A. Westgate, personal communication, 1978). Radiocarbon studies suggest a date of approximately 1250 BP for this volcanic event (Lerbekmo et al. 1975; Workman 1979, p. 349).

**Radiocarbon dates**

The six radiocarbon dates are given in Table 1. Although they form a normal sequence with depth (there are no temporal inversions), their accuracy is questionable.

The lowermost date is rejected as too old. At this level organic matter and pollen concentration are very low, whereas carbonate levels and numbers of pre-Quaternary palynomorphs are high. Excessively old radiocarbon dates frequently result from these conditions (Karrow and Anderson 1977; Mott 1975; Nambudiri et al. 1980; Ogden 1967).

The fourth and fifth lowest radiocarbon dates in the core, although somewhat more reasonable, are also judged to be too old. Uncritical acceptance of these dates would require acceptance of values of pollen influx for the period between 10 300 and 7 510 BP that are improbably low and values for the period between 10 700 and 10 300 BP that are exceedingly high. The most reasonable interpretation, in my opinion, is that old carbonates have rendered these radiocarbon determinations too old as well. Without relevant comparable dates from nearby areas, however, it is impossible to estimate the magnitude of error that is involved.

The uppermost radiocarbon date is from only 7 cm deeper in the core than the volcanic ash layer, which is dated at 1250 BP. This would suggest a depositional rate of 1 cm/162 years for this section, whereas the section above exhibits a depositional rate of 1 cm/17 years and the section below exhibits a rate of 1 cm/31 years. Once again, the drastic effect on the calculated pollen influx for this section of the core, in my opinion, is unlikely to accurately reflect the vegetational history of the region.

As a result of these various problems with the radiocarbon dates, they are considered here only as general guides to the timing of vegetational events in the vicinity of Eildon Lake. Until such time as sufficient comparative data from the region are available and corrections for the dating errors can be calculated, it would be inappropriate to use these dates for the generation of pollen influx curves for the Eildon Lake core.

**Pollen stratigraphy**

Countable densities of pollen and spores were found to a depth of 238 cm. Below this depth were only flattened pre-Quaternary fossils and a very few modern grains. Percentage trends through time for the most abundant pollen and spore types are illustrated in Fig. 3. Table 2 gives pollen and spore types that occur in trace amounts (<1.0%).

The upper 238 cm section of the core has been divided, by inspection, into three pollen assemblage zones. Zones 2 and 3 are each subdivided into two subzones. Interpretation of these zones in terms of the vegetation will be discussed following consideration of the major characteristics of the pollen assemblages.

**Zone 1 (Artemisia—Gramineae—Betula)**

This zone is the earliest, extends from the base of the core to the 202 cm level, and is bounded by two radiocarbon dates: > 30 000 and 10 700 BP. Although both dates are probably too old, they suggest that regular postglacial pollen deposition...
Fig. 3. Percentage pollen diagram from Eildun Lake. Solid shading indicates percentages and lines indicate a 5× exaggeration.
<table>
<thead>
<tr>
<th>Level (cm)</th>
<th>Aloes</th>
<th>Caryophyllaceae</th>
<th>Corinna canadensis</th>
<th>Compsostemon porphyrophyllus</th>
<th>Cruciferae</th>
<th>Epilobium</th>
<th>Fabaceae</th>
<th>Labiatae</th>
<th>Polygonum</th>
<th>Thalictrum</th>
<th>Vitisvitis</th>
<th>Dryopteris type</th>
<th>Equisetum</th>
<th>Lycopodiaceae</th>
<th>Polypodiaceae</th>
<th>Selaginella</th>
<th>Sparganium type</th>
<th>Triglochin</th>
<th>Typha</th>
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<tr>
<td>4</td>
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<td></td>
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</table>
began in Eildun Lake prior to 11,000 BP.

The zone 1 assemblage is dominated by Artemisia (sage), Betula, and various herbs, especially Gramineae, Chenopodiaceae, and Tubuliflorae. Major contributions are also made by both Salix and Cyperaceae (sedges). Sphagnum occurs only in very small amounts and only at the very base of this zone. Pteridophytes occur only in trace quantities.

Tree pollen is sparse. Over 85% of the Betula grains have diameters ≤ 20 μm. Although size-frequency distributions of Betula glandulosa and Betula papyrifera do overlap, such an abundance of grains of this small size is reasonable evidence for a preponderance of shrub birch rather than tree birch (Ives 1977). Picea and Pinus appear only in very small amounts, mostly near the bottom of the zone.

Organic matter is present in low amounts. Pollen concentration increases upward in the core, attaining values of 20,000 – 25,000 grains/mL. This is due largely to increasing amounts of the abundantly produced Betula grains.

Zone 2 (Betula–tree–Cyperaceae)

This zone extends from 202 to 156 cm. It exhibits a paucity of herb pollen grains relative to zone 1, an abundance of dwarf Betula, and the presence of tree pollen in amounts suggesting the presence of at least scattered groves of trees.

(a) Subzone 2a (Betula–Populus–Cyperaceae)

The lower boundary is dated at 10,700 BP and the upper boundary at 10,300 BP. The pollen assemblage is dominated by Betula and Populus, with Salix and Cyperaceae also making major contributions. Betula continues to be represented primarily by small grains, suggesting at least a predominance of shrub rather than tree birch. Populus rises rapidly from trace values at the base of the subzone to over 20% of the pollen sum, thereafter falling again to ~5% by the close.

Herb pollen is greatly reduced from zone 1 values except for a slight increase in Cyperaceae. Salix, although marginally decreased from previous values, continues to be a major shrub contributor. Shepherdia canadensis is nearly continuous at low percentages. Sphagnum occurs only in very small amounts and only near the close of this subzone. Pteridophytes continue to occur only in trace amounts.

Towards the close of subzone 2a, Picea occurs regularly but, at maximum, attains values of only 10–15%. Cupressinaceae, here represented by Juniperus, makes its first appearance and continues upward at low percentages throughout the core. Pinus occurs discontinuously in trace amounts.

Organic matter is present in slightly greater amounts than in zone 1. Pollen concentration reaches values of 70,000 – 90,000 grains/mL, a considerable increase over that of zone 1.

(b) Subzone 2b (Betula–Picea–Cyperaceae)

Beginning at 168 cm, this subzone continues up to the close of zone 2 at the 156 cm level, which has been dated at 7510 BP. Picea exhibits a dramatic rise to over 35%. Betula, still represented mostly by small grains, has values of about 40%, about half its former contribution. Populus also declines drastically, exhibiting only trace values by the close of zone 2. Larix first appears in this subzone but remains at very low percentages, as does Pinus. Alnus first appears as a major contributor of shrub pollen, attaining values of 5–10%. Salix and Shepherdia canadensis continue at their former values, and Myrica (sweet gale) makes its first appearance, remaining at low values throughout the subzone. Ericaceae also makes its first regular appearance. Most herbs continue at very low values, whereas Cyperaceae reaches its Holocene maximum at 10–12%. Sphagnum rises slightly in percentage contribution.

Organic matter increases to ~50% by the close of zone 2. Despite both these increased organic values and the addition of several contributing taxa, pollen concentration is reduced from subzone 2a levels.

Zone 3 (tree–Alnus–Sphagnum)

This zone extends from 156 cm to the top of the core. The pollen assemblages are characterized by a very strong representation of tree taxa and strong contributions from Alnus and Sphagnum. Picea is the dominant tree form. Betula becomes further reduced in amount and its grain size becomes greatly increased, suggesting the presence of tree birch and reduction in ground cover of shrub birch. Although numerous herb pollen types occur, none but Cyperaceae contributes more than 2% of the pollen sum.
(a) Subzone 3a (Picea—Betula—Alnus—Sphagnum)

This subzone extends from 156 to 82 cm depth in the core. It spans over 5100 radiocarbon years, with its upper boundary dated at 2380 BP. The pollen assemblage is dominated by high values (>25%) each for Picea, Betula, and Alnus. Larix and Cupressinaceae occur regularly but at very low values. Pinus also occurs regularly but at low percentages, rising to 5% only by the close of this subzone. In the latter half of this subzone 75—80% of Betula grains exhibit diameters exceeding 20 μm.

Shepherdia canadensis occurs sporadically and at trace values. Salix still appears regularly but in reduced amounts. Myrica attains values of up to 5%, becoming a major shrub contributor. Both Salix and Myrica, however, are greatly exceeded by the 30—35% contribution of Alnus.

Most herbs continue in trace amounts. Cyperaceae is greatly reduced yet remains a regular contributor at greater than trace values. Sphagnum attains values of 5—15%.

Organic matter remains at 70—80% throughout this section of the core. Pollen concentrations reach their maximum of 125,000—150,000 grains/mL in this subzone.

(b) Subzone 3b (Picea—Pinus—Betula—Alnus—Sphagnum)

This final subzone spans approximately the last 2400 radiocarbon years. The pollen assemblage remains similar to that of subzone 3a. The most striking change is the increase in Pinus to 10% over most of this subzone and to 20% by the present. Picea, Betula, and Alnus continue largely unchanged except in the immediate vicinity of the volcanic ash lens at 75 cm and in the uppermost levels of the core.

In the vicinity of the ash lens, Picea exhibits a small, brief peak, whereas Betula and Alnus show small decreases. Similar changes occur in these three taxa in the uppermost levels of the core. Larix, Cupressinaceae, and Populus continue to occur only in very small amounts.

Salix is slightly increased, whereas Myrica is slightly reduced. Both Cyperaceae and Sphagnum increase slightly. Most other taxa continue unchanged.

The amount of organic matter briefly drops in the vicinity of the ash lens and then peaks at over 95% in the uppermost levels. Pollen concentration decreases throughout this subzone as a result of decreasing compaction.

Vegetation reconstruction

Interpretation of a percentage pollen diagram requires that differential rates of pollen production, dispersion, and preservation be considered. These factors can lead to under-representation of taxa that were of major importance within the vegetation, whereas other, more minor, components can become over-represented. Major, probable effects of these factors, in the case of the Eildun Lake data, are discussed below.

Pollen influx calculations can also be useful in clarifying the relationship between the pollen spectra observed and the nature of the floral communities that produced them. For reasons that were discussed above in the section on radiocarbon dates, no influx pollen diagram has been generated from the Eildun Lake data. In one instance, however, specific influx rates will be briefly mentioned for illustrative purposes.

The pollen and spore assemblage of zone 1 represents a form of open herb tundra that does not appear to have a modern analogue (Ritchie 1977; Cwynar and Ritchie 1980). It is also likely that it was in a near constant state of change during that early postglacial period as new taxa immigrated.

Following deglaciation in the Eildun Lake region, prior to 11,000 years ago, an open and herb-dominated vegetation regime became established that was characterized by the pioneering taxa Salix, Artemisia, Gramineae, Cyperaceae, Rosaceae, Chenopodineae, Tubuliflorae, Plantago, Sphagnum, and several other herbs and Pteridophytes. It is likely that several more palynologically “silent” taxa, such as lichen and various entomophilous plants, were present as well. Shrub birches were present but likely did not constitute a very great portion of the ground cover immediately following deglaciation. As Picea and Pinus grains appear only in small amounts and mostly near the bottom of zone 1, they probably represent redeposited pollen from glacial meltwater (McAndrews 1984) rather than the presence of spruce and pine trees near Eildun Lake. Trees were likely absent from the landscape. Progressive increases in shrub pollen such as Shepherdia canadensis and Betula, however, indicate that there was an increasing complement of shrubs within the vegetation, eventually producing a shrub tundra.

Ritchie (1977, p. 414), in his work on the Campbell-Dolomites Uplands near Inuvik, Northwest Territories, compared pollen percentages from recently deposited lake sediment with vegetation cover percentages for the same taxa. He found that several taxa, such as Salix and Shepherdia canadensis, were consistently underrepresented in the sediment, whereas others, such as Betula and Cyperaceae, were overrepresented. In analyzing his M Lake diagram from the same region (in which he showed postglacial pollen assemblages very similar to those from Eildun Lake) he cautioned further that, although Artemisia and Gramineae pollen may form a major portion of the pollen sum, the influx values generated are far lower than those expected from a temperate steppe where these plants may constitute up to 60% of the vegetation cover. He concluded that the vegetation represented was an open, discontinuous, and dominantly herbaceous tundra composed of pioneering, rapidly migrating species moving in from nearby glacial refugia and that, although containing some willow, it likely had little in the way of ericads or shrub birches (Ritchie 1977, p. 420). A similar situation is here interpreted as having prevailed at Eildun Lake, with shrubs only becoming dominant in the latter portion of zone 1 time.

The Natla Bog pollen profile (MacDonald 1983) shows a zone 1 assemblage, dated at 8630—7700 BP, similar to that evident at Eildun Lake, although with a stronger initial shrub component. Because of the distance between these two sites and the differences in their ecological and geographical situations, I feel that a direct comparison of radiocarbon dates for this zone would not be appropriate. It is uncertain from the data presently available whether the increase in zone 1 Betula percentages from low levels in both the Natla Bog and Eildun Lake profiles represents an increasingly favourable climate for these shrubs or simply different migration rates among the various taxa present. The John Klondike Bog data (Matthews 1980) show no analogous pollen zone.

The direct source of species immigrating to produce the zone 1 assemblage at Eildun Lake would have been the ice-free corridor to the west, with many or all of these species originally migrating from northwestern refugia in Alaska and the Yukon (Hopkins 1972; Matthews 1974a,b; Ritchie 1977). The treelike conditions suggested by the zone 1 assemblage at Eildun Lake may thus have been the result of treelike conditions in the ice-free corridor. This contention, of course, needs further research to the west for verification.

Zone 2 represents a grove land or forest tundra. Although only partially forested conditions are suggested by the pollen
assemblages of both subzones, changes in both tree and shrub dominance within this zone suggest significant ecological changes.

The subzone 2a assemblage also represents a vegetation regime for which there is no precise modern analogue. With the beginning of this subzone, at about 10700 BP, herb pollen declined rapidly, whereas that of the shrub birches exhibited a dramatic surge to values of 60–80%. Other shrubs continued largely unabated. Ritchie’s (1977, p. 414) comparison of vegetation cover with pollen percentages in lake sediment in the Mackenzie River delta showed that pollen of the shrub birch was overrepresented by a factor of 2.6, whereas willow pollen was underrepresented by a factor of 0.61. In addition, various herbs, constituting about 55% of the vegetation cover in his study, were more severely underrepresented. Although precise adjustment factors cannot be applied accurately between areas widely separated in space and time, since different environmental parameters may apply, Ritchie’s data may be applied to the Eildun Lake assemblages as general indicators. The implication is that shrubs, in the general vicinity of Eildun Lake, constituted at least 30–40% of the ground cover, with much of the remainder, in the absence of evidence for ericads and sphagnum moss until the close of this subzone, consisting of a varied herbaceous community continuing from zone 1.

In addition to this evidence for continuation of extensive shrub-tundra coverage, subzone 2a presents the first evidence for the presence of trees in the vicinity of Eildun Lake. This evidence is manifest in the form of values of up to 20% for *Populus*. Mott (1978) cited numerous pollen profiles from across Canada where a peak in *Populus* occurs in sediments dated prior to the peak in *Picea*. Two comparable profiles of interest in this regard are those of Lofty Lake in central Alberta (Lichti-Federovich 1970) and M Lake near Inuvik (Ritchie 1977).

At Lofty Lake, *Populus* peaks at about 11,400 BP, whereas at M Lake it peaks at about 10,000 BP. At Eildun Lake the *Populus* peak of 10,700 BP is nicely bracketed by these other radiocarbon dates, as is to be expected if the ice-free corridor opening up between these other two sites is given to be the source of poplar trees colonizing the Eildun Lake vicinity. If the radiocarbon dates that bracket subzone 2a are used, *Populus* influx ranges from 600 to 1100 grains cm$^{-2}$ year$^{-1}$. These values, although somewhat higher than those reported by Ritchie (1977, p. 415) for M Lake, are generally comparable to values calculated by Mott (1978) for various other profiles.

The increasing number of reports of large *Populus* peaks in early postglacial pollen spectra is surprising because *Populus* is severely underrepresented in recently deposited surface samples (Lichti-Federovich and Ritchie 1965, 1968; Janssen 1967; Mott 1969; Davis and Webb 1975). Sangster and Dale (1961) and Havinga (1964) have demonstrated the high susceptibility of poplar pollen to destruction by oxidation. It may be that presently unknown aspects of the chemistry of the sediments in which these *Populus* peaks occur are involved in the preservation of these grains. Whatever the reasons are, the values indicated for *Populus* in subzone 2a suggest the abundant growth of these trees around Eildun Lake.

The fact that after the establishment of tundralike communities there was a considerable delay in the arrival of poplar at both M Lake and Eildun Lake suggests that the ice-free corridor was originally treeless and that poplar colonized it, and subsequently Eildun Lake, sometime between 10,700 and 10,000 BP. Poplar’s light, easily blown seeds would have encouraged its rapid spread through the ice-free corridor, permitting it to be the earliest pioneering tree in the Eildun Lake region, preceding even spruce.

Subzone 2a thus represents a vegetation regime in which groves of poplar trees grow in a landscape still largely characterized by shrub-tundra communities. The still very low amounts of organics in the sediment support this contention. Little can be stated, as yet, about the climate during the transition from zone 1 to zone 2. The sudden surge in both shrub and tree cover is consistent with the suggestion of a shift to a wetter climate (MacDonald 1983). In any such formulation, however, the effects of differential rates of plant migration into the area must be considered. The extent to which these vegetation changes are due to factors of migration rather than of climate is, as yet, uncertain.

In subzone 2b, spruce trees, which first appear in the region towards the close of the previous subzone, replace poplar as the dominant arboreal species. Schweger (1976) and Ritchie (1977) suggested that spruce migrated down the Mackenzie Valley from southern refugia. Lichti-Federovich’s (1970) Lofty Lake profile indicates a *Picea* peak shortly after 11,400 BP. Ritchie’s (1977) M Lake profile shows *Picea* peaking shortly after 8600 BP. The Eildun Lake data, indicating a *Picea* peak shortly after 9000 BP, fit well with a northward migration model for spruce in this region.

Without reliable calculations of influx, it is difficult to estimate the density of the spruce cover at that time. From the strong rise in *Picea* percentages and the significant drop in *Betula* percentages, it appears probable that arboreal communities were becoming established that were denser than those formed by groves of poplar in the preceding period. With the presence of spruce, tamarack, and sphagnum moss and the steady rise in organics it is probable that modern bogs began to form. It is unlikely, however, that there was dense forest such as characterizes the area today.

The pollen percentages of the shrub birches decline but remain much higher than the values indicated for the shrub birch component in the forest of the preceding zone. Although alder shrubs were likely present their pollen contribution remained relatively low at 5–10%. Ritchie (1977, p. 414) suggested that alder is likely to be overrepresented by as much as a factor of 10. Alder, therefore, was not a dominant shrub at that time. Other shrubs continued as a major portion of the ground cover. Willow and soapberry tend to be greatly underrepresented in the forest as a result of both masking by more numerous and more prolific pollen producers and filtering out by dense forest growth (Tauber 1967a, b). In subzone 2b, however, these taxa continue unabated from former levels. Cyperaceae is subject to the same factors of masking and filtration, yet it attains its Holocene maximum in this subzone. It is not until the end of this subzone that organics reach values similar to those exhibited in the forest of the succeeding zone. I suggest that the vegetation represented in subzone 2b, although characterized by increasing tree density through time, can best be described as a spruce-dominated forest tundra.

With the beginning of zone 3, the pollen assemblage shows a fully developed forest. The relative uniformity of the pollen spectra from the beginning of zone 3 to its close means that the forest probably has not changed greatly during the last 6500–7500 years. Relatively minor changes in the pollen spectra, however, result in the division of zone 3 into two subzones.

*Pinus* is represented more strongly in subzone 3a than in
previous zones but remains at very low percentages. The susceptibility of *Pinus* grains to long-distance wind transport produces large (>30%) pollen percentages even in areas far removed from their source (Faegri and Iversen 1975; Kroeker 1979; Mack and Bryant 1974; McAndrews et al. 1979; Ritchie and Lich-Richter 1967). The percentages observed in subzone 3a almost certainly represent such long-distance transport rather than the presence of local pine trees, but the distances involved cannot be adequately estimated. Matthews (1980), however, has demonstrated the presence of pine trees approximately 6700 years ago at John Klondike Bog. Presumably, pine has been slowly continuing its northward migration along the Mackenzie River valley since then.

Subzone 3a displays the first good evidence for birch trees in the shift to larger *Betula* grains. Although *Populus* occurs only in trace amounts, poplar trees may have been as abundant in the region then, as a successional species, as they are today. The high values for spruce indicate the continued dense growth of these trees.

Although alder is probably greatly overrepresented, its values of >25% suggest that it formed then, as it does today, a major component of the undergrowth. Reduced percentages for willow, soapberry, and sedge probably reflect the operations of masking and filtration mentioned above.

The complacency exhibited in the pollen spectra throughout subzone 3a is interesting in light of the documentation by several researchers (Terasmae 1961; Bryson et al. 1965; Bryson and Wendland 1967; Nichols 1967, 1969, 1975) of a cooler climate between 3500 and 1500 BP. This climatic deterioration resulted in a southward shift of the tree line by at least 2° latitude through limitation of regrowth following forest destruction by fire (Bryson and Wendland 1967, p. 292). Pettapiece and Zoltai (1974), in their discussion of palaeosols in the subarctic, also documented evidence for a substantial temperature decrease and an increase in soil moisture leading to frost wedging in the soil beginning about 3500 BP. They inferred from evidence of dated frost wedges presented by Tarnocai (1973) that there may have been a contemporaneous southwestern extension of permafrost as far as Wrigley on the Mackenzie River, 34 km northwest of Eildun Lake.

During the archaeological excavations at KgRi-II (Fig. 1), similar large frost wedges were discovered in the soil. These affected the provenience in the soil of the artifacts of the Northwest Microblade Tradition, dating to >2500 BP, but did not affect the placement of artifacts dating to within the last 1500 years (Losey et al. 1979, p. 75). These frost wedges are likely contemporaneous with those in the Wrigley area.

Despite this evidence for widespread climatic cooling there is no evidence in the pollen data of a concordant change in the vegetation around Eildun Lake. *Alnus*, an important indicator of boreal forest, exhibits no decrease in the latter part of subzone 3a. *Shepherdia canadensis*, an abundant plant in the region today, is obviously still subject to strong masking, a situation that did not exist in the forest tundra of subzone 2b.

When reliable influx calculations become possible for this region, corroborating evidence should be sought, but for now it appears that any opening of the forest occurring in the Eildun Lake region at that time must have been very minor. The frost wedges in the Eildun Lake area probably formed in response to small and highly localized changes in vegetation mat insulation at a time when lower temperatures were conducive to such formations (Conaty and Slater 1979). Pettapiece and Zoltai (1974, p. 289) stated that "soil features such as cryoturbation can indicate the presence of permafrost, but this does not necessarily dictate the absence of forest."

Subzone 3b represents a period of transition, with only minor local vegetation changes, of the same forest vegetation represented in subzone 3a. *Salix* and *Cyperaceae*, although slightly increased, are far from attaining the values attained in the forest tundra of subzone 2b. The major pollen change is the increase in the amount of *Pinus*, which attains values of 10–12% over most of subzone 3b and 20% at the top. As mentioned above, these percentages do not indicate the presence of many pine trees near Eildun Lake. They do suggest, however, that jack pine, migrating northward along the Mackenzie River, as suggested by Yeatman (1967), invaded the lower reaches of River-Between-Two-Mountains a little over 2000 years ago.

A relatively minor and short-lived pollen change apparent within subzone 3b is the rise in *Picea* percentages coincident with small and equally short-lived decreases in the percentages of *Betula* and *Alnus*; these changes occur at the level of the volcanic ash. It is tempting to postulate a short-term vegetation change in which plant cover or the flowering of birch and alder was decreased by the ash fall while that of spruce was not. Malde (1964, p. 7) pointed out, however, that conifers exhibit greater susceptibility to damage from volcanic ash falls than do deciduous trees. Other factors related to the probable direct effects on vegetation of the White River ash fall (Workman 1979) render these pollen changes even more difficult to explain.

### Summary

Deglaciation occurred at Eildun Lake prior to 11 000 years ago. The vegetation that occupied the newly deglaciated landscape was an herbaceous tundra composed of species that migrated from the ice-free corridor to the west. With time, the shrub component, dominated by shrub birches, increased to produce a shrub tundra. The lack of trees at Eildun Lake at this time may have been the result of treeless conditions in the adjacent section of the ice-free corridor.

Poplar invaded as early as 10 700 BP to form a grove or forest tundra. After an uncertain period of time, perhaps only a few hundred years, spruce migrated from southern refugia and replaced poplar as the dominant tree. A lengthy period followed during which a spruce-dominated forest tundra covered the area. Problems with old carbonates affecting the radiocarbon dates render this period of time uncertain, but it may have lasted 2000 years or more.

By 7000–7500 BP a boreal forest, including alder and tree birch, had developed. This forest has remained largely unchanged through to the present day. Pine trees invaded the lower reaches of River-Between-Two-Mountains by approximately 2400 BP but never became abundant near Eildun Lake.

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