ENVIRONMENTAL HISTORY OF CARIBOU BOG,
PENOBSCOT CO., MAINE

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Résumé

L'histoire de la tourbière à sphagnes Caribou Bog, localisée dans le sud de la partie centrale de l'État du Maine, est étudiée à partir du contenu en macrofossiles et en pollen d'une carotte de tourbière. Il y a 3000 ans entre l'émergence de la région de la mer et le début de la sédimentation organique. Trois environnements de dépôts montrent la succession de lacustre à marécageux, puis à tourbeux. La concentration des macrofossiles a été faible dans le sédiment lacustre qui contenait les graines des types du marais et du bord du lac. L'assemblage des macrofossiles les plus divers a été déposé dans le sedimnet du marais.

Abstract

The history of Caribou Bog, a Sphagnum peatland in south-central Maine is determined by analysis of the macrofossils and pollen from a core in the central area of the bog. There was a lag of 3000 years between the emergence of the area from the sea and the beginning of organic sedimentation. Three major depositional environments are delimited, based on the nature of the sediment matrix and the enclosed macrofossils and microfossils. These correspond to a shallow lake, marsh, and Sphagnum bog ecosystems. Macrofossil concentration was low in the lake sediment, and included taxa of marsh and nearshore environments. The most diverse assemblages were deposited in the marsh sediment.

Introduction

Raised bogs are found in eastern North America from Manitoba to Newfoundland (Glaser & Janssens, 1986), and several studies have illustrated the geographical distribution of various landform and vegetation types (e.g. Damman, 1977; Worley, 1981; Glaser & Janssens, 1986). Although large-scale geographic variations in landforms and vegetation distribution are being identified, less is known about the development and history of these peatlands.

There are several possible reasons for the development of bogs, including the growth of Sphagnum and other characteristic bog species over mineral soil (Heinselman, 1970; Griffin, 1977; Glaser & Janssens, 1986) or the infilling of lake basins (Gates, 1942; Dansereau & Segadas-Vianna, 1952). Recent work in Minnesota, for example, has shown that the extensive peatlands in the Glacial Lake Agassiz basin started developing about three thousand years ago by the paludification of prairie and forest land (Griffin, 1977). Stratigraphic studies in eastern Canada also have found Sphagnum or fen peat directly overlying mineral soil (Glaser & Janssens, 1986).

Small kettle-hole bogs may develop from the infilling of the original lake basin, although bogs of any kind may grow out over the landscape by paludification (Worley, 1981).

Little is known about the origin of bogs in Maine and there are few detailed studies about their history (Worley, 1981). Osvald (1970) described the vegetation and stratigraphy of several bogs in Maine and the Canadian Maritimes. The presence of "nekton mud" at the base of some sections suggests an aquatic phase. Similarly, Dachnowski (1926) and Dachnowski-Stokes (1929) illustrated the profiles of several New England bogs, including eight in Maine, but these descriptions differentiate only general environments such as sedimentary peat, sedge peat, or woody peat, and are undated. Tolonen & Tolonen (1984) analyzed in detail the stratigraphy of four coastal bogs in southeastern Maine, using microfossils and macrofossils to describe the history of the vegetation and environment.

The purpose of this study is to present the stratigraphy of Caribou Bog in south-central Maine and to provide a description of bog formation and succession in this area of Maine. The history of
the deposit is determined from a detailed analysis of the sediment (Gajewski, 1979) and the identification of the subfossil seeds and fruits. The pollen of aquatic and bog plants are also analyzed to supplement this macrofossil information.

**Study area**

As the most recent ice sheet receded, the sea transgressed on the isostatically depressed land and much of southern Maine, including the study area, was flooded. Rock flour from the melting ice was deposited in the sea and covered the surface with a layer of silt-clay, the Presumpscot Formation (Smith, 1985). The area emerged from the sea by about 12,000 years B.P. (Stuiver & Borns, 1975; Smith, 1985). The surface is irregularly dissected, with the primary features aligned approximately north-south to northwest-southeast.

There are two major parallel depressions in the study area aligned north-northwest to south-southeast (Fig. 1). One depression is occupied by a shallow lake (Pushaw Lake, maximum depth 8.5 m), the other by Caribou Bog and Mud Pond (elevation 37 m; maximum depth 2.5 m). Boundaries for the different wetland types shown in Figure 1 were determined from soil survey maps (USDA Soil Conservation Service, 1963). Visits to much of the peatland showed that the soil classification was an accurate indication of the vegetation type at the scale of this map. Probes of the sediment in many areas (Gajewski, 1979) indicated that the areas identified as swamp or undifferentiated wetland typically have shallow accumulations of sediment.

For this study, I concentrated on the wetlands east of Pushaw Lake, labelled Caribou Bog (Fig. 1). Caribou Bog is a Sphagnum-Ericaceae-Picea peatland, and was classified as a low shrub peatland by Worley (1981). Toward the outer edge of the bog is a narrow, discontinuous alder zone, and swamps in some places. Sediment is up to 8 m deep in the main part of the bog, consisting of Sphagnum peat overlaying fibrous peat and lake sediment (Gajewski, 1979; Fig. 2). Peat is shallower under the swamp which divides the bog into a northern and southern basin. Although the surface elevation could not be accurately measured, Worley (1981, p. 90) states that the bog is slightly raised, and Figure 2 is drawn assuming a slightly dome-shaped surface.

**Methods**

Seed and fruit stratigraphy was studied in a 5-cm diameter core collected with a Livingstone sampler. The core was located in the central part of the basin (Fig. 1), where boring indicated the deepest sediments could be found (Fig. 2; Gajewski, 1979). Lengths of 5 cm of the core were wet-sieved through 4.0, 1.0, and 0.5 mm opening screens and the remains on the sieve were analyzed for seeds and fruits. The term seed will be used henceforth to include both seeds and fruits. Primary references used to aid in identification were Fassett (1957), Gleason & Cronquist (1963), Martin & Barkley (1961), Montgomery (1977), Svenson (1929, 1932, 1934, 1939) and Wooten (1973). In all cases, the final verification of species identification was made by comparison to reference material.

The smallest sieve size used is larger than some seeds. Analysis of smaller size fractions of several samples added only an occasional seed. This is surprising since many small seeds may be expected in these environments, e.g. Typha, Kalmar, Ladum, and Juncus. Other workers (Birks, 1976; Tolonen & Tolonen, 1984) have found these taxa in sediments. The fibrous nature of much of the peat, and the large amounts of material re-
Figure 2. Cross section of Caribou Bog. The surface of the bog was assumed nearly flat. Vertical lines indicate the depth to the silt-clay layer, and the large dot indicates the location of the core analyzed in detail.

Samples of 5 mL of sediment were dried overnight at 100°C to determine percent water, and ignited at 550°C for three hours to determine percent weight loss on ignition. The latter result is an index of organic matter (Bengtsson & Enell, 1986). Sections of 5 cm (or in two cases 10 cm) of the core were submitted for radiocarbon dating.

Pollen were counted from several levels of the core to gain further information about the bog history. Samples of sediment (0.5 mL) were processed using standard methods (Faegri & Iversen, 1975). Some of the peat samples were sieved through a 212-μm sieve to remove coarse fragments, and the lowest sample, consisting of silt-clay, was processed following Cwynar et al. (1979). The residue was counted at 550 X magnification to a pollen sum of between 300-500 grains of upland plants. Nomenclature follows Gleason & Cronquist (1963).

Results

Depth of the organic sediment at the coring site (Fig. 1) was 751 cm above the grey silt-clay. In spite of several changes in the sediment type, the sedimentation rate is uniform for the past 9000 years.

The number of seeds recovered from the sediment ranges between 0-352 seeds/100 cm³ (Fig. 3). Samples below 600 cm (>8000 yr B.P.) contained few seeds — always less than 18, but typically less than 3 seeds/100 cm³. Najas and Typha seeds are restricted to the sediment between 600 and 730 cm. Occasional seeds of aquatic plants such as Sagittaria are present, as are seeds of Betula.

The most diverse seed assemblages occurred between 400 and 600 cm. Between 12 and 131 seeds/100 cm³ were recovered in this section of the core. Several aquatic taxa, including Brasenia Schreberi, Nuphar variegatum, Potamogeton spp., and Sagittaria latifolia are consistently present. There are no trends in the abundance of these types, but they are never found above 450 cm (6000 yr B.P.). Seeds of nearshore and wet-ground taxa such as Bidens cernua and Lycopus spp. are present in the sediment. Seeds of these types are not found in the sediment above 400 cm, but are sporadically represented in sediment greater than 600 cm. The sedges are well represented in this section of the core. Several samples contain seeds of Chamaedaphne calyculata, Betula, Larix and Alnus rugosa.

By 4500 yr B.P., the bog mat was at or near the location of the core. The sediment above 400 cm contains increasing amounts of Sphagnum (Gajewski, 1979) and the seeds present are of Chamaedaphne calyculata and Andromeda glaucophiphylla. Several levels contain seeds of the sedges and Betula. The concentration of seeds is quite variable in this section, ranging between no seeds in the uncompacted peat between 30-40 cm to 352 seeds/100 cm³ in the sediment from 300-305 cm. This variability is due primarily to the large numbers of Chamaedaphne seeds found in the sediment in several levels.

Pollen of aquatic plants are sporadically but consistently present in the sediment between 400-800 cm, and Pediastrum fossils are abundant below 500 cm (Fig. 4). In this section of the core, the percent weight loss on ignition increased, reaching values greater than 95 % by the end of this period. Cyperaceae pollen were relatively abundant between 300-500 cm, in a sediment classified as fibrous peat. In the uppermost 300 cm, Ericaceae pollen and Sphagnum spores
increased. The percent weight loss on ignition approached 99% in the Sphagnum peat.

Pollen of Ulmus, Acer and Fraxinus, which include species that today are found in the swamps surrounding the bog, are too rare to show any long term trends. Similarly, Alnus, which today grows in thickets between the marginal swamps and the central bog, remained constant at less than 5%.

The development of the upland forests of the region can also be interpreted from Figure 4. Only more abundant pollen types are plotted, as the major interest in this study is in the succession of the lowland vegetation. The following zones, delineated by changes in the major upland tree taxa, nevertheless correspond to the "classical" pollen zones of New England (see Gaudreau & Webb, 1985).

Zone I, sediment older than 9400 yr B.P. was characterized by high percentages of Picea, Betula and Cyperaceae pollen. This pollen was deposited in the grey silt-clay that underlies the whole area, whereas the remainder of the core consists of organic sediment. During Zone II, from 9400 to 6000 yr B.P., Picea and Pinus banksiana/resinosa pollen decreased to negligible values, while Pinus strobus dominated the pollen input. Betula pollen percentages decreased in this zone. Tsuga pollen increased and Fagus first appeared. Quercus pollen percentages were high, reaching a peak of 12% around 7800 yr B.P.

In Zone III, P. strobus pollen decreased to less than half the value attained during Zone II, and was replaced by Betula, Tsuga and Fagus. Quercus pollen percentages decreased to values less than in Zone II. Tsuga pollen decreased from nearly 40% to less than 10% between 6000 and 4000 yr B.P., and subsequently increased to about 30% by 2000 yr B.P. Zone IV shows a slight increase in Picea, a decrease in Tsuga and Fagus, and slight increases in Gramineae and other herb pollen.

Discussion

The basal 14C date, which dates the transition from inorganic grey silt-clay to organic brown gyttja is 3000 years younger than the date of emergence of the region from the sea following glaciation (Stuiver & Borns, 1975; Smith, 1985) and 1000 years younger than basal dates from coastal bogs (Tolonen & Tolonen, 1984). This silt-clay layer underlies the entire basin, and the transition to organic gyttja was usually abrupt (Gajewski, 1979). Emergence of the coastal area of Maine in response to the removal of the weight of ice.

![Figure 3. Macrofossil diagram of Caribou Bog.](image-url)
had occurred by 12,000 yr B.P.; this date is determined from numerous shells associated with nearshore conditions in the Presumpscot Formation (Stuiver & Borns, 1975). However, basal dates of freshwater sediment from a number of kettle-hole bogs can be as young as 10,000 to 12,000 yr B.P., implying a lag in the accumulation of freshwater sediment of 2000 years (Stuiver & Borns, 1975). The usual explanation for this lag—that the kettle-holes were filled with ice that didn't melt due to cold conditions (Florin & Wright, 1969)—doesn't seem applicable to Caribou Bog,
which is much too large and presumably of different origin than smaller kettle-hole bogs. The presence of pollen and *Pediasstrum* microfossils in the uppermost part of this inorganic sediment suggests deposition in an unproductive lake, and much of the sedimentation was resuspended glacio-marine silt-clay. Perhaps the abrupt change from silt-clay to organic sediment was due to a change in lake level, associated with the uplift of the land.

The macrofossil and pollen analysis suggests a successional sequence beginning with open water and a transition through marsh/sedge meadow to *Sphagnum* bog. The earliest sediment includes seeds of *Najas flexilis* — open water plants of neutral to mildly alkaline water (Helquist & Crow, 1980). Birks (1973) found abundant seeds of *Najas* in the uppermost sediment in lakes where the plant is today growing, suggesting a low abundance of plants in Caribou Bog at this time, or that *Najas* plants were growing some distance from the core site. Seed deposition is intermittent in this sediment, and the seeds deposited come from several habitats — open water (*Najas*), shallow water (*Typha, Sagittaria*), and nearshore (*Lycopus*). Birks (1973) found that although more seeds are deposited in the sediment near the plant, there can be considerable transport of seeds within the lake, particularly of seeds that can float (e.g., *Bidens, Sagittaria*). *Pediasstrum* fossils (Fig. 4) are also indicative of open water, and show a long term decrease when the sediment changes from gyttja to fibrous peat.

There are abundant macrofossils of marsh and shallow water plants (e.g., *Sagittaria, Nuphar, Brasenia*) in the lake by about 7000 yr B.P. Gauthier & Grandtner (1975) found *Nuphar variegatum* in nearshore habitats in bog lakes in Québec, and Dansereau & Segadas-Vianna (1952) considered *Nuphar* in association with other aquatics such as *Nymphaea, Potamogeton* and *Sparganium*, to be the early stages of bog succession in eastern North America. Presence of *Dulichium arundinaceum* and *Brasenia Schreberi* suggests mildly acidic water (Birks, 1980) by around 8000 yr B.P. Seeds of *Brasenia* and *Nuphar* tend to be underrepresented in the sediment compared to their plant abundance (Birks, 1973). Presence of *Bidens cernua* suggests some exposed mud along the shore surface (Birks, 1980). *Bidens* is well dispersed within a lake (Birks, 1973), and the presence of seeds in the sediment does not mean that *Bidens* plants were necessarily in the immediate vicinity of the core site. *Eleocharis* seeds tend to be less abundantly dispersed (Birks, 1973) and the large numbers of seeds in the sediment between 450 to 550 cm suggest the presence of plants nearby.

The pollen diagram differentiates an aquatic phase, with abundant *Pediasstrum* microfossils, and pollen of aquatic and marsh plants, and a bog phase, with abundant *Sphagnum* spores and Ericaceae pollen. Pollen of aquatic pollen types (e.g. *Typha, Sparganium, Potamogeton, Sagittaria, Brasenia, Nuphar, Nymphaea*, and *Lemna*) are primarily restricted to the sediment below 300 cm. Although it is not possible to use any one of these types to identify the depositional environment, collectively they suggest the presence of open water and/or marsh conditions. As pollen are well-mixed in a lake, these pollen could be transported from some distance away. The marsh phase (as interpreted in the macrofossil diagram) is identified in the pollen diagram only by a peak in Cyperaceae pollen between 300 and 500 cm; however, this information can only supplement the interpretation from the macrofossil diagram, as Cyperaceae plants are found in many different habitats from the tundra to the prairies. It is difficult to further differentiate the succession in the aquatic phase based on pollen alone, due to the small numbers of pollen deposited in the sediment, and the large vertical extent of the pollen deposition of each taxon.

Pollen of aquatic plants are concentrated in the gytta and fibrous peat sections of the core, while *Sphagnum* spores and Ericaceae pollen are abundant in the *Sphagnum* peat. The upper four metres of sediment contain seeds of the bog heaths, but it is not possible to further identify different bog communities with these data. Ericaceae and *Sphagnum* pollen are found throughout the whole sediment column, although both pollen types are more abundant in the uppermost 300 cm of sediment.

One characteristic of seed deposition is the large variation in seed concentration between adjacent samples. The between-sample variance is much greater than is present in pollen samples, which typically show greater continuity between samples. In the Caribou Bog core, even adjacent samples can show quantitatively different seed assemblages. In spite of this variability, the overall development of Caribou Bog is recorded by the seeds and they provide useful information about the paleoenvironments of the bog.

Caribou Bog developed from a shallow lake. There was initially a period of 3000 years between the uplift of the area above sea level, and the beginning of organic sediment deposition. In the lowest portion of the core, when the area was a shallow lake, seed deposition was low, perhaps due to the long distance from shore, or to a low density of plants in the lake. As plants grew nearer to the location of the coring site, the seed diversity
increased and taxa of marsh and shallow water were deposited in the sediment. The seeds of aquatic taxa decreased as the core site became a bog, and finally only seeds of bog taxa were deposited.

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References


