SOME ASPECTS OF AMMONIA FIXATION

BY PEAT
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By

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SCOPE AND CONTENTS: Examination of peat samples collected from hummocks and hollows within a confined bog reveals that peat collected from different locations, designated by surface topography, vary in ash content, ash alkalinity, initial Kjeldahl nitrogen content, and fixed and total nitrogen after ammoniation with an ammonia-air mixture. The values of these properties have shown hummocks and hollows to be true entities having characteristic ranges of certain properties.

The results have shown that, although peat is heterogenous with respect to certain properties, use can still be made of determined values if ranges of these values are recognized and utilized. Misinterpretations and meaninglessness of results are possible if this is not done.
The motivation behind this investigation was primarily a desire to find some direction to the solution of how surface topography of a bog develops. It was hoped that the discoveries arising out of this study would contribute to an understanding of certain differentials noted when peat changes in relation to topographic dynamics, especially with respect to the hummock-hollow association.

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INTRODUCTION

Much work has been done to elucidate the complex pathways of the biogeochemical nitrogen cycle in soils. Now, a general workable understanding of this cycle exists, although mechanisms and controlling factors of few of the associated steps are completely understood. Of the investigations that have been done on this topic, most have been directed towards organic matter in mineral soils and not in peat. In mineral soils the role of microorganisms, water movements, leaching, and other features of the microenvironment, as they tend to affect organic matter, have been studied. These processes vary with geographical location, soil classes, climatic conditions, and time. It is very difficult therefore to make generalizations on the effects and application of these processes, particularly when dealing with peat.

Bremner (1952, page 500) has stated:

"The present information regarding the nature of soil nitrogen complexes is very unsatisfactory. The chemical nature of a considerable fraction of the soil nitrogen is unknown and information regarding the nitrogen complexes that have been identified is inadequate. It is equally clear that until more extensive information regarding nitrogen complexes is obtained we cannot hope to achieve a proper understanding of their roles in the nitrogen cycle or of the factors affecting their availability to plants."
In peat too, information on the forms and chemical behaviour of the nitrogen complexes is nebulous or lacking. Essentially, this is for two major reasons. Firstly, fewer workers have directed their attention to peat than to mineral soils. Secondly, work done on mineral soils in many cases cannot be applied directly to peat because of the differences in structure and chemical behaviour of the components.

There is also a lack of knowledge of the chemistry of peat components (particularly colloids and lignin), plant deposition, and breakdown processes (Sjörs, 1950; Bremner, 1952). Even now, although the trend is to oppose this, many compounds in humus and peat are defined by the techniques used to extract them (Bremner, 1952; Ponomareva and Nikolayeva, 1961). Not only is the chemistry of the constituents vague, but also the forces influencing the physical and chemical transformations of these substances and their importance relative to one another are still uncertain. Yefimov (1962, page 643) has stated recently that there is "almost a complete lack of unified analysis of the system: peat producers-peat soils – soil water whereas there is a huge amount of unrelated analytical data on peat."

A large portion of research on origin, form, and behavior of peat pertains to areas drained for forestry, agriculture, or the peat processing industry (Sjörs, 1961). Prior to analysis, the natural condition of the bog has been modified, usually by drainage and removal of the surface vegetation (Sjörs, 1961). This generally brings about a subsequent lowering of the water level, accompanied by increased aeration and oxidation (Gorham, 1961; Heinselman, 1963; Vidal, 1963). These changes may enhance aerobic microbial activity (Paariahti and Vartiovaara,
1958; Paarlahti, 1959) and accelerate changes in properties of the peat (Waksman and Stevens, 1929; Nikonov and Minkina, 1962). If this occurs, peat texture, the colloid state (Nikonova and Minkina, 1962), peat chemistry, and peat permeability (Paarlahti and Vartiovaara, 1958) may be altered. The conditions, as indicated by the results of these investigations, may not be equivalent to the conditions existing in undisturbed bogs and therefore, explanations of phenomena present in drained bogs may require significant qualification if they are to be regarded as meaningful for unaltered bogs (Sjörs, 1961).

In their natural condition bogs differ from one another in water content (Vidal, 1963). Whatever the difference, the content varies because of evapotranspiration and run-off from the bog and sources of replenishment to the bog. The water entering the bog comes either from the atmosphere as direct precipitation or from mineral terrain as run-off and ground water. If most of the water comes directly from the atmosphere, the bog is termed "ombrogenous", if most of the water has come by way of mineral terrain the bog is termed "geogenous". (Heinselman, 1963).

Use of this terminology may lead to difficulty. Previously these terms applied to the different kinds of "wet of soil" (Swedish markblöta, German bodennasse) and were used to describe the water in the bog and not the bog itself (Sjörs, 1948, page 279). Presence of substances in the water (for example, solid particles and dissolved salts) may be implied without qualitative and quantitative restrictions, when these terms are used. Short-comings of this system of classification
arise because of lack of sufficient quantitative information on other sources of water present and imperfect assessment of the influence of nutrients transported by these other forms of water and of the nutrients from all other sources as well.

Bogs receiving most of their water directly from the atmosphere (ombrogenous) have surface vegetation dependent on the atmosphere for nutriment (Mattson and Koutler-Andersson, 1954). Precipitation may remove "dust" from the air and may contain dissolved gases and various chemical compounds. Solid matter may settle out of the air onto the bog directly. Gases in the atmosphere may become dissolved in surface water of the bog depending on the ratio of concentration of gas in the solution to the concentration of gas above the solution at a given temperature (Handbook of Chemistry and Physics, 1963, page 3258). Chemical reactions of these gases with peat components may lower the partial pressure of the gas in the peat water.

Of the many substances that arrive at the bog surface from the atmosphere, some can be utilized immediately by plants for growth. Others may become available for plant uptake after further chemical changes and some may not be absorbed at all. If only small amounts of some elements are needed, these are called trace elements or micronutrients (Thomas, 1958). Other elements, however, are termed "essential" or macronutrients (Thomas, 1958) and are required in larger amounts (for example, nitrogen). Various forms of nitrogen present in the atmosphere are absorbed directly by growing plants and other forms are made available by microbial action. If only part of the entire
surface of a bog is dependent primarily upon the atmosphere for the element, the availability and usefulness of chemical forms of it should be examined. Some nitrogen-fixing organisms are now known to exist in peat (Paarlahti and Vartiovaara, 1958) and in plants growing on bogs (Bond, 1951, 1963), but generally nitrogen gas does not play an important role as a source of nitrogen for bogs. Ammonia, or ammonium ions, and oxides of nitrogen may arrive at the surface of a bog as gases or trapped by precipitation.

Mattson and Koutler-Andersson (1954, page 324) have stated:

"among the gaseous constituents of the atmosphere ammonia and nitrogen oxides occupy an important position in the development of the raised bog inasmuch as these gases must be assumed to supply most of the nitrogen required by plants. The bog must be assumed to get more than its share of the nitrogen because no matter how low the gaseous pressure of the ammonia in the air, it must be lower in the highly base unsaturated peat. There must be a constant flux of ammonia from the air into the bog, apart from that which is brought down by the rain."

Once in contact with the peat, the ammonia is held securely or "fixed". Peat and mineral soils are known to retain atmospheric ammonia, in contrast to other forms of nitrogen, by physico-chemical fixation (Mattson and Koutler-Andersson, 1954; Sohn and Peech, 1958). Many aspects of this phenomenon have not yet been investigated in peats.

This project was undertaken to examine the phenomenon of ammonia fixation by peat. The proportion of this form of nitrogen to the total
nitrogen content of the peat, before and after ammoniation, is evaluated in relation to other selected properties of the peat and to the surface topography, especially that of the hummock-hollow association, of a bog.
CHAPTER I
A REVIEW OF THE LITERATURE ON AMMONIA FIXATION

Ammonia fixation has been known to take place in mineral soils over a century ago (Malo and Purvis, 1964) and in peat more recently (Mattson and Koutler-Andersson, 1943, 1954, 1955; Koutler-Andersson, 1960; Maksimow and Grudzinski, 1950; Bremner, 1952; Maksimow et al, 1963). Although the result, the fixation of ammonia or ammonium, is similar the substances and mechanisms involved are not necessarily the same. Possibly an approach to the study of ammonium fixation in peat may have developed from that dealing with this reaction in mineral soils.

A brief examination of ammonia fixation by mineral soils will be considered first and aspects of it will be compared and contrasted with that occurring in the review of the literature on ammonia fixation by peat.

A. Ammonia Fixation by Mineral Soils

In a brief survey of the literature, Malo and Purvis (1964) reported that Liebig in 1847 suggested that soils may absorb atmospheric ammonia. They also reported that Bretschneider, in 1872, and Schlossing were among the first to make quantitative estimations regarding this phenomenon. Since that time various aspects of absorption and fixation of ammonia and ammonium ions by soils have been studied.

Although Ingham (vide Malo and Purvis, 1964) stressed the importance of organic matter in soil, most of the attention,
with the exception of Mortland (1955) and Sohn and Peech (1958), has been directed towards the inorganic fraction, particularly the clay components, as they affect ammonia fixation. The clay minerals to which fixation is mainly attributed are illite, vermiculite, and montmorillonite (Nõmmik, 1957; Stojanovic and Broadbent, 1960; Welch and Scott, 1960). Nõmmik (1957, page 395) reported that

"it has been suggested that fixation involves replacement by \( \text{NH}_4^+ \) and \( K^+ \) of interlayer cations (\( \text{Ca}^{++}, \text{Mg}^{++}, \text{Na}^+ \)) in an expanded lattice of micaceous clay minerals. This replacement results in contraction of the crystal lattice and in an entrapment of the interlayer \( \text{NH}_4^+ \) and \( K^+ \). Cations of the contracted lattice can be replaced slowly by cations that expand the lattice."

Stanford and Pierre (1946) (reported by Nõmmik, 1957, page 395) have shown that

"ammonium and potassium, having almost the same ionic radii, are fixed by the same mechanism. Thus, if potassium salts were added to the soil prior to the ammonium, the amount of ammonium fixed was reduced in proportion to the amount of potassium previously fixed."

Dhariwal and Stevenson (1958) report similar competition between \( \text{NH}_4^+ \) and \( K^+ \).

There exists no general agreement with reference to the best method for the determination of ammonia (Harper, 1924) or of

"Barshad (1951) proposed to define the 'fixed' NH$_4^+$ as the NH$_4^+$ which is not replaceable by prolonged extracting and leaching the soil with K$^+$ salt solutions".

More recently Allison and Roller (1955, page 361) stated: "Fixed or difficulty exchangable NH$_4^+$ can best be defined as that NH$_4^+$ which is not removed by extraction with 1 N KCl". Methods used for quantitative determination of fixed ammonia are: KCl leaching (Harper, 1924; Allison and Roller, 1955; Nõmmik, 1957; Stevenson, 1959; Dashevskiy, 1960; Stojanovic and Broadbent, 1960), KOH/NaOH distillation (Allison and Roller, 1955; Hanway and Scott, 1956; Nõmmik, 1957; Leggett and Moodie, 1962), dilute acid leaching (Mayboroda, 1961), dilute acidified salt solution leaching (Sohn and Pech, 1958) mild alkali distillation (Harper, 1924), and K$_2$CO$_3$ or Na$_2$CO$_3$ aeration (Harper, 1924; Leggett and Moodie, 1962). With most of these methods, a known amount of NH$_4^+$ is added as a salt solution and the amount not extracted is considered fixed. Dashevskiy (1960) has considered the adsorbed ammonium to be present in three forms, according to the strength of combination with the adsorption complex. These are: (1) readily exchangeable - that NH$_4^+$ extracted by one treatment of 1% KCl, (2) exchangeable with difficulty - that removed only with repeated KCl extractions, (3) nonexchangeable - that not extracted even with prolonged washing of
the soil with 1 N KCl. Mayboroda (1961, page 206) has stated:
"There is little dissolved ammonium in soils. It is mainly absorbed by colloids from which it is practically impossible to extract with water."

In addition to ionic competition, other variables have been found to affect ammonia fixation of soils quantitatively. Several workers (Nõmmik, 1957; Mayboroda, 1961) have shown that ammonium fixation by mineral soils is strongly decreased quantitatively as the pH of the soil decreases. Walsh and Murdock, (1960) showed that removal of water from soil, after NH$_4^+$ addition increases fixation of NH$_4^+$.

The effects of the moisture content and pH on ammonia fixation by soils have been presented as a comparison for the variables affecting ammonia fixation by peat in which water and acidic conditions are important.

B. Ammonia Fixation by Peat

Investigations of nitrogen in peat have been made for several decades. In the early 1930's, Feustel and Byers (1933) reported that "much work has been done in trying to make enriched [with nitrogen, primarily] peat a fertilizer". This enrichment was brought about by an addition of ammonia to peat at high temperatures and pressures (Feustel and Byers, 1933). The major problem encountered was the availability of this added (and firmly bound) nitrogen for plant utilization. Work on this problem is being continued mostly in Europe (Minnesota Peat Mission to Europe, 1958).

Attention has been directed also toward the natural nitrogen
content of peat. All the forms in which nitrogen exists in peat are still not known. Although quantitative analyses of some nitrogen compounds have been made, that remaining after subtraction of the amount of known forms from the total nitrogen content has been grouped into categories established by extraction techniques. Waksman and Stevens (1928a) divided the total nitrogen in peat into three fractions:

"(1) Soluble in cold and in hot water; this includes ammonia, nitrates, amino acids, and soluble proteins and is the smallest fraction in peat. (2) Nitrogen hydrolyzed readily by dilute acids; this fraction can be considered as the true protein nitrogen. (3) Nitrogen not readily acted upon by the above acid treatment." They added that these three groups account for all of the nitrogen. They also state that "although the water-insoluble nitrogen is recorded as protein, it does not necessarily exist entirely in that form in peat." This general group has been used as a matter of convenience, (Waksman and Stevens, 1928b). "Peat contains a considerable amount of nitrogen in a very resistant form. This may be referred to as 'humin nitrogen' (Waksman and Stevens, 1928a). This fraction may account for one-third of the total nitrogen in lowmoor and one-half of the nitrogen in highmoor peat (Waksman and Stevens, 1928b).

Kupreenko and Logvinova, (in Waksman and Stevens, 1929, page 327) found that "sphagnum peat contains a large quantity of its nitrogen in the form of adsorbed ammonia." "This phenomenon was naturally explained by the high content of absorbed ammonia in the sphagnum peat, but no explanation was suggested for the origin of this ammonia". (Ibid)
Mattson and Koutler-Andersson (1943) reported that humus possesses the natural capacity to fix large amounts of ammonia. Extending their investigations to peat, they found that the ability to fix ammonia existed there too. This fixed ammonia was found to have come from microbial ammonification and the atmosphere (Mattson and Koutler-Andersson, 1943). These authors examined this phenomenon considering the prerequisites for and variables involved in ammonia fixation, the substances which can fix ammonia, the results of ammonia fixation on the organic matter, and suggested theoretical mechanisms involved in this investigation.

When investigating the variables involved in ammonia fixation, Mattson and Koutler-Andersson (1943) found that lignin played an important role and that previously unoxidized lignin fixed most of the ammonia in the presence of oxygen and that very small amounts of ammonia were fixed under anaerobic conditions. They (Ibid) also found some correlation between ammonia fixation and the alkalinity of the ash of the peat. It was determined that the lower the alkalinity of the humus and litter, the greater was the amount of ammonia fixed. "All peat formed under conditions of low base status undergo autoxidation and ammonia fixation in the presence of oxygen if even a moderate amount of alkali is added", (Ibid, page 344). Investigating the chemical composition of peat profiles, Mattson and Koutler-Andersson (1954) determined that a negative correlation exists between nitrogen content and "excess base". This excess base or ash alkalinity was determined by finding the equivalents of base present in the ashed peat sample.
In connection with the base status, it was found by these workers, (1943), that there was a decrease in fixation of ammonia with an increase in acidity of the peat.

Organic substances capable of fixing ammonia were investigated. Mattson and Koutler-Andersson (1943, page 133) determined that "water soluble and lignin fractions fix more ammonia per unit weight of organic matter than the whole sample." Large amounts of water soluble materials which possess the power of ammonia fixation are also soluble in alcohol (Ibid).

Attempting to obtain more information on ammonia fixation by lignin Mattson and Koutler-Andersson, (1943) extracted lignin from different sources. They found that two general forms of lignin exist, as determined by ammonia fixation capabilities. Lignin from green leaves is about as active in ammonia fixation as that from ripe litter, but wood and straw lignin is less active. They (Ibid, page 130) referred to the "active" type as "functional lignin" and the less active (woody) type as "structural lignin". In addition to this it was determined that "lignin from a base-unsaturated area is much more active than the lignin from base-saturated soil. The latter has been autoxidized and has fixed ammonia in nature to a much greater degree than the former" (Ibid, page 115). By doing ammoniation of peat samples in the laboratory these two workers, (1954), showed that the sum of the fixed nitrogen and the initial nitrogen is closely correlated with the lignin content in a peat profile.
Organic compounds of known structure were examined by Mattson and Koutler-Andersson (1943) for ability to fix ammonia. This investigation revealed that "glucose, fructose, di- and triatomic phenols, gallic and tannic acids fix large amounts of ammonia, the aromatic compounds as much as 14%" (Ibid, page 134).

The ammonia which is fixed by peat is in a nonexchangeable form and the ligno-nitrogenous complex is chemically very stable (Ibid). The ammoniated complex is very stable toward acids and even the strongest acid dissolved less than ten percent of it. Much fixed ammonia is removed even by magnesium hydroxide and 2N sodium hydroxide removes almost one half of it (Ibid).

These authors (1954) determined the amount of fixed ammonia as follows. They found the initial Kjeldahl nitrogen content, and then took a similar sample and shook it with 12% ammonia solution in the presence of oxygen. The sample was then acidified with HCl and washed free from salt with dilute acid and then with water. A Kjeldahl nitrogen determination was made of the peat residue. This value then presented the sum of the initial nitrogen and the ammonia fixed. By subtracting the original from the final nitrogen content the amount of nitrogen fixed was determined.

Organic compounds which have fixed ammonia are chemically altered in the process. Coloured water-soluble compounds of litter and humus become water insoluble and soluble organic matter becomes acid-insoluble after ammoniacal autoxidation. Substances having fixed ammonia take on a deeper colour. The autoxidized and ammoniated solvates
assume a distinctly amphoteric character. The fixed ammonia lowers the capacity of humus and peat to bind base and raises the base status and therefore raises the pH (Ibid).

The mechanism involved in the fixation of ammonia by peat components is not fully known. Mattson and Koutler-Andersson (1943) showed ammonia fixation to be an oxidation reaction. Although there appears to be no strict parallelism between autoxidation and ammonia fixation, if one is small the other is small. Mattson and Koutler-Andersson (1943) considered that the strong reducing power developed in the lignin, resulting in rapid autoxidation and ammonia fixation, occurred because the presence of the ammonia catalyses the fixation of ammonia by raising the base status of the lignin. At low pH, the base binding capacity of peat is higher the lower the nitrogen content. This particularly affects mono- and divalent cations which are too mobile to be cumulative in bogs except where there is a high base-binding capacity (Mattson and Koutler-Andersson, 1954). These authors (1943, page 120) also proposed that "the basic nitrogen in the humus functions as electropositive groups, each of which compensates an electronegative group, either by direct linkage or by virtue of their electric fields. This reduces the polar attraction on the solvent dipoles and reduces the solvation." Because the fixed ammonia lowers the capacity of humus to bind base, Mattson and Koutler-Andersson (1943), thought this indicated that the basic nitrogen formed an inner salt with the carboxy group, thus compensating for the acidity and at the same time suppressing the properties due to this acidity.
CHAPTER II
ATMOSPHERIC NITROGEN

If bogs, particularly those which are predominantly ombrogenous, receive most of their nitrogen supply directly from the atmosphere, a brief qualitative and quantitative assessment of sources and forms of this element present in the atmosphere would be helpful for assessing the importance of fixation. This chapter is concerned with informing the reader of the concentrations of various forms of nitrogen in the atmosphere, sources of these compounds, conditions under which they vary, and supplying a detailed analysis of atmospheric ammonia.

Nitrogen occurs in the atmosphere as nitrogen gas ($N_2$), oxides of nitrogen, ammonium ions ($NH_4^+$), and ammonia ($NH_3$). Nitrogen gas is the most abundant form representing $78.084 \pm 0.004\%$ of atmospheric air, excluding water vapour. Although much less than nitrogen gas, nitrous oxide ($N_2O$) is the next most abundant form, being present in the concentration of $0.5 \pm 0.1$ ppm (parts per million) of dry atmospheric air (Handbook of Chemistry and Physics, 1963). The other forms of nitrogen are usually less abundant. Eriksson (1952) reported ammonium concentrations in the atmosphere to be about $0.007$ to $0.87$ mg.$/m^3$ (milligrams per cubic meter). Malo and Purvis (1964) in 1961 found atmospheric ammonia concentrations to be from a trace to $0.22$ mg.$/m^3$ for the period July through October for New Brunswick, New Jersey, with a daily average of $0.06$ to $0.15$ mg.$/m^3$ for individual four day periods.
Oxides of nitrogen come predominantly from the oxidation of nitrogen gas, mostly by electrical discharge during electrical storms, but also by photochemical reactions and from meteorite trails (Angström and Högberg, 1952). Angström and Högberg (1952) proposed the following reaction brought about by energy supplied by the sun:

\[ 6 \text{N}_2 + 18 \text{H}_2\text{O} \rightarrow 4 \text{NH}_4\text{NO}_3 + 4 \text{NH}_4\text{OH} + \text{O}_2 \]

With this reaction the ammonium produced is twice as much as the nitrate produced. These workers thought that on a world-wide scale there is an almost constant ratio of 2:1 in which ammonium nitrogen and nitrate nitrogen respectively appear in precipitation and they believe accordingly that this reaction would account for this. They (Angström and Högberg, 1952) hypothesized that this reaction would transform about three percent of the nitrogen present to give present concentrations of ammonium and nitrate in precipitation. Some oxides of nitrogen sometimes are released in considerable amounts by certain industries. Nitrous oxides and nitrogen gas are also produced in the denitrification of nitrate and nitrite by microorganisms and concentrations of these forms vary with the degree of anaerobiosis of the soil or organic matter (McElroy and Glass, ed., 1956).

Ammonia and ammonium ions are derived primarily from the combustion of organic matter (Mattson and Koutler-Andersson, 1954). This may occur in nature as a result of fires and slow decay of organic matter. However a source of ammonia in some industrialized areas is the combustion of organic fuels and the ammonia is present in the air as a contaminant (Eriksson, 1952). Malo and Purvis (1964, page 244).
attributed the unusually high NH₃ content of the air they sampled in New Brunswick to "NH₃ residues from coal, oil, and gasoline consumption". Another very important source is the ammonia released to the atmosphere with the use of ammonium fertilizers, particularly on basic soils, and on the addition of lime to fertilized soils (Eriksson, 1952). These sources may be of considerable magnitude in agricultural areas. Ammonium nitrogen may also arise from the Angström and Högberg photochemical reaction.

Although it is not a source for areas as far inland as the bog examined by the author, sea water may contribute ammonium nitrogen to bogs along the sea coast. The influence of the sea as a source of ions has been intensively investigated particularly in the United Kingdom and Europe. The influence of the sea is greatly controlled by the distance from the sea and prevailing winds for the carrying of the spray.

Another source of nitrogen that Eriksson (1952) thought should be included as a source of nitrogen to the atmosphere is the nitrogen, mostly in the form of ammonia, present in rocks. He reported that Hutchinson had found that igneous rocks contain about 0.005% nitrogen (by weight) and sedimentary rocks about 0.051% nitrogen (0.046% being biochemically fixed). This form of nitrogen is very likely to be released very slowly but may be more important during volcanic activity (Mason, 1960), being found in limited quantities in lava, volcanic effusions and crater gases (Encyclopaedia Britannica, Vol. 1, 1957). Ammonia released by volcanic activity would be of significance in very limited areas of the world.
Concentrations of nitrate nitrogen and ammonium nitrogen vary with location and time. Ammonium nitrogen concentration in the atmosphere is highest at the equator and decreases with latitude until it is least at the polar regions where the concentration may be only 50% that at the equator (Angström and Högberg, 1951). Nitrate is also highest in the tropics (Angström and Högberg, 1951). Eriksson (1952) reported that the ammonium content of the atmosphere has two maxima, one in the spring and one in the late summer, but Malo and Purvis (1964) discovered that NH₃ concentrations were highest in April and May and lowest in the period July through October. The minimum occurs during winter. The nitrate nitrogen maxima vary less with the season and more with the rainfall but usually occur about one and one-half months after the ammonium nitrogen maxima (Eriksson, 1952).

The ammonium nitrogen content of the air varies with the amount of precipitation having fallen previously (Angström and Högberg, 1951) and with sources of replenishment. These variables bring minor minima and maxima in concentrations of ammonium nitrogen within the larger trend stated above. Very important factors with which the ammonium nitrogen does not vary are the frequency of electrical storms (Angström and Högberg, 1952) and the annual amount of rainfall (Eriksson, 1952). Variations in atmospheric NH₃ content have been found to be as great from day to day at one location as between different locations (Malo and Purvis, 1964).

NH₃ content of rainwater was found to be significantly higher in the relatively dry months. Malo and Purvis (1964) found that each
acre-inch of precipitation contained slightly more than 0.2 lb. NH₃-N and that approximately 8.3 lb. N/acre was contained in the annual precipitation. The concentration of ammonium nitrogen in precipitation reaching the surface of a bog (or field) also varies with the form of precipitation (Eriksson, 1952). Generally the ammonium concentration increases as water droplet size decreases. Therefore fog and very fine rains contain more of this form of nitrogen than rains made up primarily of large droplets (Eriksson, 1952). The ammonium concentration also tends to be higher in forms of precipitation derived closer to the ground. Dew is generally very rich in ammonium particularly nitrogen (Eriksson, 1952). This would be true particularly in regions of high rates or organic decay and regions of intense nitrogen fertilization. This source would be generally very low in arid regions where little organic matter exists.

Extensive investigations of ammonium nitrogen in the atmosphere have not been done because ammonia is not considered a common atmospheric contaminent in cities. In a review of the literature Eriksson (1952) found a minimum in the amount of ammonium and nitrate nitrogen brought to earth by precipitation of 1.9% kg./ha./yr. In this review he reported an average ammonium nitrogen content reaching the earth at Ottawa, Ontario, of 0.98 kg./ha./yr. between 1908 and 1924, but there was an increase every year. The city of Hamilton, Ontario, Municipal Laboratory on Smoke, reported ammonium nitrogen to be very

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1. Personal communication with Hamilton Air Pollution Laboratory, June 9, 1964.
scarce in the atmosphere of that city, less than 0.01 ppm. (parts per million). A study was made of NH$_3$ in 1959 and 1960 in the area surrounding the American Cyanamid factory, a company producing urea at the time. Here the ammonia concentration in the air was 0.00-0.10 ppm. 84%, 0.11-0.20 ppm. 9.5%, 0.21-0.50 ppm. 6%, 0.51-1.0 ppm. 0.8%, and more than 1.1 ppm. 0.6% of the time, throughout these two years. This increase could be detected only in the immediate vicinity of the factory. The nitrogen trichloride method of analysis used was claimed to be accurate to 0.01 ppm.\textsuperscript{2}

Information presented here has shown that the concentration of ammonia in the atmosphere is very low and variable with respect to some other forms of nitrogen and many other gases in the atmosphere. A mechanism by which this form of nitrogen, an essential element, can be used may be of significant ecological importance, if the utilization of more abundant forms of nitrogen is not possible.

\textsuperscript{2} Personal communication with Hamilton Air Pollution Laboratory, June 9, 1964.
CHAPTER III
COPETOWN BOG

The area from which samples were taken is a bog, referred to as the Copetown Bog or Summit Bog (Spencer Creek Conservation Report, 1960), situated along Highway 52, about two-thirds of a mile south of Copetown, just within the northern border of Ancaster Township, Wentworth County, Ontario (Atlas of the County of Wentworth, 1960). The location is approximately 43°14' N. and 80°03' W. and is slightly less than 800 feet above mean sea level (Topographic Map, Brantford Sheet, 1934).

The bedrock underlying the bog is dolomite of the Guelph Formation of the Silurian Period. This overlies dolomite of the Lockport Formation which is the bedrock just to the north-east of the bog. These formations overlie deposits of Rochester shale; Clinton dolomite, limestone, and shale; Medina sandstone, shale; and limestone; and shale of the Queenston Formation (Spencer Creek Conservation Report, 1960; Atlas of the County of Wentworth, 1960).

Physiographically, the surrounding terrain is classed as kame moraine and outwash (Spencer Creek Conservation Report, 1960). The characteristic features are hummocky, sandy areas of water washed sands and gravels, dissected by drainage patterns (Spencer Creek Conservation Report, 1960). The soil is sandy loam, with varying amounts of clay, tending to be stony and shallow (Spencer Creek Conservation Report, 1960).
The dominant Great Soil Groups are Grey-Brown Podzolic, and, in poorly drained areas, Dark Grey Podzolic (Matthews and Baril, 1960). According to land capability classification, the mineral terrain in the region of the bog varies from being "suitable for cultivation with simple to intensive practices", particularly concerning erosion control, to being "suitable only for permanent vegetation with moderate to severe restrictions" (Spencer Creek Conservation Report, 1960; "Recommended Land Use" Map).

In the Atlas of the County of Wentworth (1960) the dividing line between the Grand River and Spencer Creek Systems is indicated as the eastern edge of the Copetown Bog, however, the bog is under the jurisdiction of the Spencer Creek Conservation Authority (1960). The salient feature is that this bog lies right on the watershed. Although free water is present within this bog, no inflowing stream can be found. A culvert which was constructed presumably to restore the natural drainage system which may have existed before the road was constructed, exists at the southern end of the bog but water flow is detectable only during high water (Stewart, 1963). Undoubtedly the bog receives some water as run-off from the road and railroad embankments and from the mineral slopes to the north but this would seem to be a small amount in comparison with the total water content of the bog. The presence of occasional mineral laminae in the peat (Ibid) well within the periphery of the bog indicates that silt-clay bearing waters have covered at least parts of the bog briefly during its development. It is suspected that much of the water content of the bog is derived from a water table or
spring(s) directly under the bog (Ibid). Evidence points to the condition that the present bog area was once open water (Ibid). A high water level exists in spring, after snow thaw and spring rains. This is followed by a decrease in water content at the bog surface as a result of evapotranspiration and some runoff.

Sulphur Creek, part of the Spencer Creek System, arises to the east of the bog from mineral springs, many of which are saline or sulphurous (Spencer Creek Conservation Report, 1960). The dolomitic rocks of the Guelph and Lockport Formations supply water good in quality and quantity, but waters from the Queenston, Median, and Clinton Formations may contain much iron, sulphur, and sodium chloride (Ibid). The qualitative and quantitative information on the water which feeds the bog is not available. It is assumed that the source is water table or springs. The water from the small pond within the bog has been used in the past as a source of water from steam locomotives on the nearby railroad and for watering of livestock (Stewart, 1963).

The climate is also an important variable which affects development of vegetation on the bog. The Copetown Bog lies just south of the 45°F. annual isotherm which marks the northern boundary of the "Lake Erie Counties", a region having one of the most favourable climates for agriculture in Ontario (Putman and Chapman, 1938). The length of the growing season is 190-200 days and the frost-free season is 140-150 days (Ibid). The average winter temperature is about 23°F. and the average summer temperature is about 67°F (The Climate of Canada, 1962; Putman and Chapman, 1938). The average precipitation is reported to be less
than 32 inches of which 6 inches represents about 60 inches snowfall (The Climate of Canada, 1962; Spencer Creek Conservation Report, 1960). The prevailing winds are from the south-west (Spencer Creek Conservation Report, 1960).

The bog itself is approximately 2000 ft. by 850 ft. and has an area of about 28 acres (Stewart, 1963). The pond, north-east of the centre of the bog, is reported to be over 45 ft. (14m.) in depth. A discontinuous lagg exists with a water content which varies with the season. Stewart's records indicate a maximum peat depth of about 7.5m. (Ibid). The mineral matter below the peat is silt with some clay and sand (Ibid).

The living vegetation is very characteristic of many other bogs which the author has seen near Parry Sound, Ontario, and many of Radforth's coverage formulae (Radforth, 1952) are present. As far as the author knows, the vegetation, especially that near the centre of the bog, has been altered little except for the decapitation of a few spruce trees for use as Christmas trees. Quite likely the water regime has been altered considerably by the building of the road and railroad embankments but now the effect of this on plant associations is difficult to assess. It is apparent that garbage left along the edge of the bog next to the road and soil washed down from the surrounding mineral terrain have affected the lagg vegetation. The intense use of fertilizers and road salt likely would contribute to this change, especially in the last few decades. The utilization of these ions by lagg vegetation and absorption of ions by the peat probably has confined increased salt
concentration to the outer margin of the bog.

The peat samples were obtained from an area extending from about 550 ft. west-south-west of the small bog pond to the approximate centre of the bog. There is a transition of the vegetative types from IEF-EIF, according to the Radforth Coverage classes (Radforth, 1952) at the peripheral sites, to BEI at the more central ones. The peripheral regions are composed of very low hummocks with a thick growth of Sphagnum sp. in the wet hollows. The vegetation on the hummocks from which samples were taken is Chamaedaphne calyculata (L.) Moench, Sphagnum sp. with some Vaccinium oxycocccus L., Polytrichum commune L., and seedling Picea mariana (Mill.) B.S.P. and Larix laricina (Du Roi) K. Koch. The vegetation of the hollows in which samples were taken is primarily Sphagnum sp. with some V. oxycoccus, Calla palustris L., Drosera rotundifolia L., and Sarracenia purpurea L. In the BEI region the microtopography is of the accentuated hummock - hollow type. Here the hummocks are in various stages of development from low rolling wet ones with vigorously growing Sphagnum sp. and large sharp-sided ones with relatively dry tops, to decaying hummocks whose structure is presently deteriorating, showing bare peat. Hummock vegetation where samples were collected is C. calyculata, V. oxycoccus, Sphagnum sp., P. commune on wetter hummocks; C. calyculata, V. oxycoccus, Sphagnum sp., P. commune, and grasses on the dryer hummocks; and, on the degenerating hummocks, mostly P. commune, C. calyculata, various grasses and forbs, and Cladonia sp. The hollows in the BEI region contained standing water in June and little vegetation was present.
These hollows are mostly of bare peat or peat sparsely covered with *Sphagnum* sp., *D. rotundifolia*, and *V. oxycoccus*. Gases with the odour of hydrogen sulphide emanated from these hollows if pressure was applied to the surface of the peat. The B vegetation of the BEI is *P. mariana* and *L. laricina*, which are usually somewhat deformed. For further information on the floristics of the entire bog the reader is referred to Stewart (1963, pages 228 to 231).
A. **Collection and Handling.**

Peat samples were removed from hummocks and hollows using 12 oz. tin containers. These cans were prepared by cutting off both ends and sharpening the edge of one end.

Excess living vegetation, for example woody branches of *Chamaedaphne* sp., was removed from the spot in which the sample was to be taken. The can was then pushed down into the peat with a short clockwise and counter-clockwise twisting motion to cut the fibres present. With the can at the proper depth, the surrounding peat was removed and the sample was cut off at its base with a knife. As the can containing the sample was removed most of the water was retained by placing a hand under the open bottom. Then the sample was transferred to a glass jar. About 1 to 2 ml. toluene (Mayboroda, 1961) was added to the sample and the jar was covered with a plastic lid to prevent loss of water and excess aeration.

In the laboratory, the gravitational water was allowed to drain out of the samples. This water was filtered and its pH was determined. The peat was then squeezed by hand and the water which was extracted filtered and its pH was determined.

The peat was divided longitudinally into four or more pieces and allowed to air dry while resting on, and covered with, paper towels.
and filter paper in a room in which no ammonia was used.

Once air dried, sufficient peat was taken from this sample to provide subsamples of about 2 g. each. These were then weighed and given the appropriate treatment.

B. Description.

Samples of series A were collected on May 6, 1964, those of series B on June 11, 1964, and those of series C on July 2, 1964.

Site A: EFI hummock in EFI-FEI area I.


2. Location: top of a well-defined hummock in full sun all day.


4. Moisture condition: damp (very little water able to be squeezed out by hand) to dry-damp (enough water present to prevent peat from becoming powdery when rubbed).

5. Peat description:

   (a) vegetation: about equal amounts of dark brown *P. commune* and light brown *Sphagnum* sp. with fine grass and fine-to-medium-fine, long, woody fibres of *V. oxycoccus* and *C. calyculata*.

   (b) structure: fibres orientated vertically; sample difficult to separate on a horizontal axis but easy to separate on a vertical axis.
(c) state of humification: mostly little decomposed, H2, but showing a range from H1 to H3.

Site B: IE hollow in EFI-FEI area I.

1. Samples: A2, B4, C3.
2. Location: hollow immediately south of Site A.
3. Vegetation: mostly darkly coloured bare peat with some young P. commune, Sphagnum sp., V. oxyccoccus, and, near the base of hummocks, C. calyculata.
4. Moisture condition: very wet (free standing water).
5. Peat description:
   (a) vegetation: mostly Sphagnum sp. and P. commune with pieces of sedge; fine woody fibres of V. oxyccoccus; leaves of C. calyculata and V. oxyccoccus.
   (b) structure: amorphous granular peat held in a loose mossy mesh; some matting on a horizontal plane.
   (c) state of humification: mesh: H1 to H3; interstitial material: H6; considerable range of change present.

Site C: IE hollow in EFI-FEI area II.

2. Location: hollow between low and poorly developed hummocks in a treeless region between the lagg and the BEI region.
3. Vegetation: mostly Sphagnum sp., with C. calyculata and
V. oxycoccus.

4. Moisture condition: very wet with much free water in May but considerably less in July.

5. Peat description:

(a) vegetation: two distinct types of peat were present:

(1) thin surface layer of little decomposed Sphagnum sp. with woody fibres (less than 5.0 mm. in diameter) of V. oxycoccus.

(2) much more decomposed layer, mostly of indistinguishable plant remains but having woody fibres and leaves of V. oxycoccus and C. calyculata; fine grass, Sphagnum sp.; sedge culms near bottom of sample.

(b) structure: (1) loose and spongy; (2) dense mesh of very fine fibres holding smaller fragments; matted on a horizontal plane.

(c) state of humification: (1) very slightly, if at all, changed; H1 to H2.

(2) much more decomposed with only most resistant parts still recognizable; dark brown in colour drying to light brown with black leaf fragments; H5 to H6.

Site D: EIF hummock in BEF-BFE area III.

1. Samples: A4, B8, C5.

2. Location: top of a well developed hummock (1½ ft. high)
receiving sun throughout the entire day.

3. Vegetation: *Sphagnum* sp., *C. calyculata*, *V. oxycoccus*, fine grass; growth was not luxurious.


5. Peat description:
   (a) vegetation: almost entirely *Sphagnum* sp. with some fine grass; fine fibres of *V. oxycoccus* and some coarser ones of *C. calyculata*; entrapped leaves of *C. calyculata* and *V. oxycoccus*.
   (b) structure: typical loose mesh of *Sphagnum* sp. with some reinforcement with woody fibres.
   (c) state of humification: generally little decomposition of *Sphagnum* sp. with leaves of other plants exhibiting a great range of decay; H2. Peat light brown with slight reddish tint, drying to light reddish brown.

Site E: hollow in BEF-BFE area III.

1. Samples: B7, C4.

2. Location: hollow, immediately east of hummock at site D.

3. Vegetation: dark bare peat with some *Sphagnum* sp.; *V. oxycoccus* present but rooted at the base of surrounding hummocks and not in the hollow.

4. Moisture condition: wet (some free surface water present in June, very little free water present in July).
5. Peat description:

(a) vegetation: (1) a thin surface layer of *Sphagnum* sp. with woody shoots and leaves of *C. calyculata* and *V. oxycoccus*.

(b) structure: (1) loose mesh of *Sphagnum* sp.

(2) loose mesh of fine, non-woody fibres reinforced with woody fibres.

(c) state of humification: (1) light brown *Sphagnum* sp., very little decomposed; H1 to H2.

(2) greatly decomposed with more than half of the material not botanically identifiable; leaves fragmented and black; H5.

Site F: hummock at edge of BEI area IV.

1. Samples: B6, C11.

2. Location: large, well-defined, elongated hummock with dense growth of *Picea mariana* (Mill.) B.S.P. at one end (end not investigated).

3. Vegetation: *Sphagnum* sp., *C. calyculata*, some *V. oxycoccus*, and some short "layered" branches of *P. mariana* nearby.


5. Peat description:

(a) vegetation: almost entirely light brown *Sphagnum* sp. with *V. oxycoccus* and some *C. calyculata* roots and shoots; entrapped leaves of *C. calyculata*
and V. oxycoccus.

(b) structure: loose mesh of Sphagnum sp. with horizontally orientated fine woody fibres.

(c) state of humification: little decomposed Sphagnum sp.; H2; blackened leaves of C. calyculata and V. oxycoccus.

Site G: hollow at edge of BEI area IV.

1. Sample: B5.

2. Location: small hollow (8 in. by 12 in. surface area) in hummock at Site F; hollow about 2 ft. below top of hummock.

3. Vegetation: mostly bare peat with some Sphagnum sp.

4. Moisture condition: wet, some free surface water.

5. Peat description:
   (a) vegetation: small amount of Sphagnum sp., mostly leaves and some roots and short twigs of P. mariana.
   (b) structure: generally no mesh; peat loose and crumbly when dry.
   (c) state of humification: peat very dark with advanced decomposition; H4 to H5.

Site H: hollow at edge of BEI area IV.

1. Sample: Cl2.

2. Location: small hollow on side of hummock (Site F) opposite Site G; slope of side of hummock very steep.


5. Peat description:
   (a) vegetation: *Sphagnum* sp., leaves of *P. mariana*, *V. oxycoccus*, and *C. calyculata*.
   (b) structure: fine, non-woody fibrous peat; tightly matted; some fine, long, woody fibres; separates with some difficulty on a horizontal axis.
   (c) state of humification: some of the mosses are little decomposed but generally vegetation is fragmented and black in colour; H5.

Site I: hummock in BEI area V. (Area of well-defined hummock-hollow associations).

1. Samples: B9, C6.

2. Location: top of hummock about 2½ ft. high; in mottled shade of trees much of the day.

3. Vegetation: *Sphagnum* sp.; fine grass, small *P. mariana*, and some *V. oxycoccus*; FIE.


5. Peat description:
   (a) vegetation: *Sphagnum* sp., fine grass, fine woody shoots of *V. oxycoccus*, leaves of *C. calyculata*, and *V. oxycoccus*.
   (b) structure: loose mesh of *Sphagnum* sp., grass shoots,
and roots with scattered woody fibres of
V. oxycoccus.

(c) state of humification: Sphagnum sp. light reddish-
brown to light grey-brown and little decomposed;
H1 to H2; leaves decomposed almost beyond
recognition.

Site J: hummock in BEI area V.

1. Sample: B12, C8.
2. Location: well-defined hummock, southern slope shows
mechanical breakdown and erosion; in full
sunlight throughout the day.
3. Vegetation: P. commune, C. calyculata, V. oxycoccus,
Cladonia sp.; EIH; growth poor.
5. Peat description:
   (a) vegetation: mostly P. commune with small amounts of
Sphagnum sp.; few woody fibres and leaves of
C. calyculata and V. oxycoccus.
   (b) structure: fibres orientated vertically giving pulpy
effect; peat crumbles when dry.
   (c) state of humification: medium-to-dark brown when dry;
decomposition advanced; H4.

Site K: hummock in BEI area V.

2. Location: well-defined hummock south of site J. Top and
southern slope of hummock show mechanical breakdown and erosion.

3. Vegetation: bare peat with poor growth of *P. commune*, *C. calyculata*, and some brown *Sphagnum* sp.


5. Peat description:
   (a) vegetation: mostly *P. commune* with some *Sphagnum* sp. and fine grass; few woody fibres and leaves of *C. calyculata* and *V. oxycoccus*.
   (b) structure: vertically orientated fibres of *P. commune* interwoven with woody fibres; little mesh present; tends to be spongy when damp but crumbles easily when air dried.
   (c) state of humification: mechanical breakdown advanced; peat very dark brown with light brown *Sphagnum* sp.; leaves fragmented and black; much material not identifiable; H4 to H5.

Site L: hollow in BEI area V.


2. Location: elongated hollow immediately north of site I.

3. Vegetation: mostly bare peat and brown *Sphagnum* sp. with *V. oxycoccus* creeping in from the surrounding hummocks.

5. Peat description:
   
   (a) vegetation: most constituents beyond botanical recognition; leaves of *C. calyculata*, *V. oxycoccus*, and *Sphagnum* sp.; woody shoots of *P. mariana*, *C. calyculata* and *V. oxycoccus* present.

   (b) structure: tightly matted clumps built up of a mesh of fine fibres; hard and not spongy when dry; much amorphous granular peat present.

   (c) state of humification: wide range of decomposition present but most of peat H5 to H6.

Site M: hollow in BEI area V.

1. Samples: B11, C7.

2. Location: hollow immediately south of site J.

3. Vegetation: no living vegetation, only darkly coloured *Sphagnum* sp. and bare peat.


5. Peat description:
   
   (a) vegetation: *Sphagnum* sp.; fragments of leaves of *V. oxycoccus*, and *C. calyculata*; sedge culms, short woody twigs. Much of the vegetation not botanically identifiable.

   (b) structure: amorphous granular peat held in a loose open mesh of non-woody fibres; dries to form very hard mass.

   (c) state of humification: most of the matter well decayed; H6.
Site N: hollow in BEI area V.


2. Location: elongated hollow between steeply sloped hummocks.

3. Vegetation: Sphagnum sp., P. commune, V. oxycoccus.


5. Peat description:

(a) vegetation: (1) thin outer layer of Sphagnum sp., and P. commune with woody fibres of C. calyculata and V. oxycoccus.

(2) thicker under-layer of Sphagnum sp., woody fibres and leaves of C. calyculata and V. oxycoccus.

(b) structure: (1) weak mesh of mosses with some reinforcement with woody fibres.

(2) loose discontinuous mesh of non-woody fibres but presence of interwoven woody fibres makes separation of the peat difficult.

(c) state of humification: (1) medium brown colour with decomposition evident; H3 to H4.

(2) leaves black and fragmented; some material not botanically identifiable; H4 to H5.
CHAPTER V

METHOD

A block of predominantly Sphagnum peat, which had been air dried in the laboratory for more than ten years, was selected for the development of a method to be used for nitrogen determinations and ammoniating procedures. The faces were trimmed and discarded. Shavings, tending to uniformity in colour, texture, and plant composition, were removed from the remaining block of peat. After the few woody fibres were removed, the shavings were blended in a Waring Blender for 5 minutes. The blended peat was then placed in a jar and shaken. Samples from this jar were reblended. These reblended samples were transferred to another jar and reshaken. About 60 grams of air dried peat was prepared in this way. The largest plant remains which were recognizable without magnification in this sample were individual Sphagnum sp. leaves. Samples for analyses were composed of a sufficient number of small batches of about 0.2 grams each of which was removed from the jar using a small spatula.

This peat was light brown in colour and very little decomposed. Although no water was present the degree of humification was estimated to be about H2 on the von Post Humification Scale (Healey, 1961).

A second bulk sample was prepared from fresh amorphous granular type peat which had been collected in the fall of 1963 in a bog north of Parry Sound, Ontario, and had been air dried in the laboratory. This
when wet was dark olive-to-black amorphous granular peat with occasional light coloured non-woody fibres and occasionally a woody fibre. On the von Post Humification Scale this peat was H9. When air-dried the peat formed a dark brown-to-black, very hard mass. Thin lenses and layers of charcoal were present in the peat.

This sample was blended and mixed in the manner already described. The resulting fine-to-medium-fine powder with some small, short, non-woody fibres was stored in a tightly capped bottle.

In the digestion of peat by the Kjeldahl method, 1 to 2g., preferably 2g. (Malmer and Sjörs, 1955), samples of weighed peat were placed in a 500ml. Kjeldahl flask with 10.0g. K₂SO₄, 1.0g. HgSO₄, and 30 ml. concentrated H₂SO₄ (Wilson and Wilson, 1958). These chemicals and all others used were Fisher "Certified" Reagents. The flask contents were mixed and gently heated, with the flask tilted at a 45° angle. When frothing ceased the intensity of the heat was increased until full heat was applied and the mixture boiled vigorously. During heating the flask contents were swirled to flush down organic matter lodged on the wall of the flask above the boiling mixture. Heating was continued for the required period of time after the mixture "cleared". With the amorphous granular peat the digestion progressed to a stage at which the mixture was still faintly coloured and opaque but no change in these visible characteristics occurred with further heating. This characterized the "cleared" condition.

Comparisons of Kjeldahl nitrogen contents of digestions of blended peats were made for digestion periods of 2 and 3 hours after clearing.
Comparisons of nitrogen contents of digestions of blended samples were made for digestion periods of 2 hours (Wilson and Wilson, 1958), with or without modification to include "azo or nitro derivatives" (Willard, Furman and Bricker, 1956, page 161) and with or without the addition of hydrogen peroxide to assist in digestion. For Kjeldahl digestion to include the nitro derivatives (Paech and Tracey, 1955, Vol. I), a 2 g. peat sample was placed in a 500ml. Kjeldahl flask with 10ml. of a solution containing 0.430 g. salicylic acid for every 100 ml. of concentrated H$_2$SO$_4$. The sample was then thoroughly mixed with this solution and allowed to stand for at least thirty minutes. Then 0.70 g. sodium thiosulphate was added and the contents were heated for 1 minute longer after copious white fumes were produced. The contents of the flask were allowed to cool and then 10.0g. K$_2$SO$_4$, 1.0 g. HgSO$_4$, and 30 ml. concentrated H$_2$SO$_4$ were added. When the effect of H$_2$O$_2$ was being investigated, 1-2 ml. of 30% H$_2$O$_2$ was added to the flask contents after the above chemicals. The heating was carried out in the manner previously described.

When the period of time after clearing was completed the digested mixture was allowed to cool. During the cooling process and during storage small beakers were placed over the ends of the flasks to prevent contamination. The flask contents were then slowly diluted with 200 ml. of distilled water, and the contents were shaken until most of the salts went into solution.

Several boiling chips were added and the flask with its contents was connected directly to a distillation apparatus (Fig. 8).
After connection of the distillation apparatus, the drawn glass tube was immersed as deeply as possible in a solution of 25.0 ml. of 0.10 N H₂SO₄ and several drops of indicator contained in a 250 ml. Erlenmeyer flask which was tilted to make the acid solution as deep as possible (Fig. 8). When required, 50.0 ml of the 0.10 N H₂SO₄ was used when the peat sample contained more equivalents of nitrogen than were contained in 25 ml. of this acid. The acid was measured by either a 25.0± 0.03 ml. or 50.0± 0.05 ml. Corning, Class A, NBS-C 602 transfer pipet. A 45% solution of NaOH was placed in the separatory funnel and was added to the flask contents dropwise. Excess of this base was added to make the flask contents basic. Care was taken that there was always some alkaline solution left in the separatory funnel to detect any loss of ammonia through this passage. As the final base was added, gentle heat was applied. Until the first distillate began to flow bubbles were emitted by the drawn tube in the collecting acid. After distillate had begun to collect the heat was regulated so that bubbling in the acid collector no longer occurred. Distillation was continued until 125 ml. of distillate was collected. Heating was stopped then and the stopcock on the separatory funnel was opened to prevent the drawing back of the distillate and acid into the condenser.

The acid of known volume and concentration was then back titrated with NaOH with a normality of 0.05-0.06 to a methyl red/methylene blue end point of grey. This indicator was prepared by dissolving 0.0636 g. methyl red and 0.0319 g. methylene blue in 70ml. of 95% ethanol (Ponomareva and Nikolayeva, 1961). This NaOH solution was prepared
according to the procedure recommended for the preparation of carbonate free decinormal sodium hydroxide solution in the chapter concerning standard solutions for Volumetric Analysis in the Handbook of Chemistry and Physics (1963, page 1660). This base was then titrated with 0.10 N \( \text{H}_2\text{SO}_4 \) (Fisher Scientific SO-A-220) to the phenolphthalein end point (first sign of pink).

For all chemical procedures a reagent blank was used. This involved using all the same amount chemicals and following all steps of the procedure with the exception of the presence of peat. One reagent blank was used with every group of Kjeldahl digestions made at any one time.

For oven dried peat, the samples were spread out evenly on open glass petri dishes and placed in an electric oven at 105°C (Malmer and Sjörs, 1955, Tibbetts, 1963) or some other desired temperature. Oven dried samples were stored in a desiccator with CaSO\(_4\) as the desiccant.

Preliminary analysis of the blended samples was done with distilled water, but analysis of the Copetown Bog samples was done with "equilibrium water". Air was bubbled through dilute sulphuric acid to remove traces of ammonia, then through water to remove droplets of acid spray, and then it was passed through a cylinder of glass wool to remove dust. This "purified air" was then bubbled through the distilled water for 6 hours. This produced distilled water with a CO\(_2\) content in equilibrium with the air (Kolthoff and Sandell, 1959).

For the ammoniation of samples using \( \text{NH}_4\text{OH} \), concentrated \( \text{NH}_4\text{OH} \) solution was placed in a petri dish, containing glass wool, in the
bottom of a vacuum desiccator jar. The sample on a petri dish rested on a porous disc shelf. The jar was slightly evacuated using a water filter pump. The samples were then left a desired period of time.

Ammoniation of the samples using gaseous ammonia was done in the apparatus shown in figure 9.

Samples were ammoniated in this apparatus by spreading the sample over the bottom of the 200 l. flask and immersing this in the water bath and leaving the ammonia-air mixture passing through it for 6 hours. Ammonia-air mixture was then passed slowly through the system with the flow controlled by a needle valve on the gas regulators attached to the air and ammonia tanks. The flow of ammonia and air was controlled according to predetermined rates and allowed to continue for 6 hours. At the end of ammoniation period the ammonia flow was stopped and the filter pump was connected to the acid ammonia trap outlet. While partial vacuum was applied, air was allowed to flow through the system. This was done to allow as little ammonia as possible to escape into the room when the peat sample was removed. The ammonia sample was placed in a glass container covered with filter paper, and placed in the fume cupboard until the odour of ammonia was no longer present.

The sample was then subdivided, weighed, and stored in individual 50 ml. beakers which were tightly covered with polyethylene sheeting. If the sample was not used immediately, it was reweighed just before being analysed. The samples were individually mixed with distilled water (50 ml./g. peat) and washed with another 100 ml. of distilled water in small volumes to remove free and readily available ammonia. This
filtrate was discarded.

Exchangeable ammonia was extracted with KCl. The damp sample was then mixed with 1 M KCl (1 g. peat to 25 ml. 1 M KCl) (Kaila, Koylijarvi, and Kivinen, 1953) for 30 minutes (Harper, 1924; Kaila, Koylijarvi, and Kivinen, 1953), filtered, and the residue washed with an additional 25 ml. 1 M KCl in small amounts and then with 50 ml. of distilled water. A drop of HCl was added to the filtrate to prevent escape of ammonia.

The total filtrate was distilled with an additional 150 ml. distilled water and 2.0 g. MgO (Harper, 1924; Nömmik, 1957; Kaila, Koylijarvi, and Kivinen, 1953) to make the solution basic. Boiling chips were added and the distillate was collected in the same manner as that used for Kjeldahl distillations. There were 125 ml. (Harper, 1924) of distillate collected in 25.0 or 50.0 ml. 0.10 N H₂SO₄ and titrated to the methyl red/methylene blue end point with the base used for titrating distillates of the Kjeldahl digestions.

A Kjeldahl digestion was done on the residue from the KCl extraction. The filter paper used in the previous filtration was included in the digestion. A similar filter paper, with the same procedure applied to it except for the addition of peat, was included in the digestion with the reagent blank.

The amount of nitrogen initially present in the samples was calculated as:

1 equivalent weight of NaOH reacts with 1 equivalent weight of H₂SO₄ in the titration.
l equivalent weight of NH₃ reacts with l equivalent weight of 
H₂SO₄ in the distillation. Therefore the number of equivalent weights of NH₃ neutralizing a certain 
amount of H₂SO₄ is the same as the number of equivalent weights of NaOH 
neutralizing this same amount of H₂SO₄.

x ml. of y N NaOH contains 

\[
\frac{39.999 \times \text{x ml.} \times y \times \frac{1}{1000 \text{ ml.}}}{39.999}
\]

equivalent weights 
of NaOH which is equivalent to the same number of 
equivalents of NH₃ and also of N.

This amount of NaOH is then equivalent to 

\[
39.999 \times \frac{x \text{ ml.} \times y \times \frac{1}{1000 \text{ ml.}}}{39.999} \times 14.008 \text{ g. Nitrogen}
\]

The number of equivalents of NaOH in the x ml. is the same number 
of equivalents of NH₃ distilled and is arrived at by subtracting the 
volume of base required to neutralize the remaining acid in the distillate 
from the volume of base required to neutralize the acid from the reagent 
blank distillation. The above equation then may be multiplied by the 
distillation correction factor. The distillation correction factor was 
determined by distilling a known weight of dried (105°C until constant 
wt.) (NH₄)₂ SO₄, using the above described procedure, and determining 
the amount of nitrogen present by back titration of the distillate 
collected in acid of known concentration and volume. The distillation 
correction factor was then:

\[
\frac{\text{actual weight of Nitrogen in } (\text{NH₄})₂\text{SO₄ used}}{\text{weight of Nitrogen present calculated by titration}}
\]

This factor may be included to compensate for lack of complete
efficiency in the nitrogen recovery in the distillation procedure. The distillation was carried out in association with a reagent blank. Weights of \((\text{NH}_4)_2\text{SO}_4\) used were selected to determine the range of the weight of nitrogen used.

The general equation applied to the calculation of amount of nitrogen present in a sample was:

\[
\text{base volume difference} \times \text{base normality} \times 14.008 \times 10^3 \times \text{Distillation correction factor}.
\]

This gave the amount of nitrogen present in grams.

The nitrogen present was expressed as a percentage of the sample weight as:

\[
\frac{\text{g.N.}}{\text{g. wt. of sample}} \times 100
\]

The amount of nitrogen determined in the sample before ammoniation was termed the initial Kjeldahl nitrogen content, \(N^0\) Kjeldahl. The amount of nitrogen determined by distillation of the KCl extract of the ammoniated sample gave the amount of readily exchangeable \(\text{NH}_4^+\) and free \(\text{NH}_3\) in the sample. Nitrogen present in the residue digested after the KCl extraction was given the term \(N^A\) Kjeldahl.

The amount of ammonia fixed, \(N^A_F\), by the peat sample was determined by subtracting the initial Kjeldahl nitrogen content from the Kjeldahl nitrogen content of the ammoniated sample.

\[
N^A_F = N^A\text{ Kjeldahl} - N^0\text{ Kjeldahl}
\]

The ash content and alkalinity were determined in the following manner. A sample of the peat being investigated was oven dried at 105°C to constant weight (Malmer and Sjörs, 1955; Tibbetts, 1963). This
weighed sample was then placed in a weighed, clean, moisture-free porcelain crucible. The covered crucible with its contents was heated gently until smoking stopped. The heat was then increased until the crucible was red and ashing was continued. The crucible containing its ash was then transferred to a desiccator jar. The crucible and ash were weighed after being allowed to reach room temperature (in excess of 2 hours). The ashing was continued until constant weight of the crucible and its contents was obtained.

The ash was then mixed with 25.0 ml. 0.10 N HCl (Gorham, 1953) filtered, and the filtrate and washings were back titrated with dilute NaOH of known normality to the phenolphthalein end point. A reagent blank was always done. The ash alkalinity or excess base was expressed as milliequivalents of base per 100 g. oven dry peat (Puustjärvi, 1957; Koutler-Andersson, 1960).
CHAPTER VI
RESULTS OF ANALYSIS OF PEAT SAMPLES FROM COPETOWN BOG

A. pH Determinations of Water Extracted from Samples.

Sufficient water was not available in the samples taken from tops of hummocks to make pH determinations with the equipment available.

The filtered gravitational water taken from the samples collected in hollows had a range in pH from 4.30 to 5.53 with an average of 4.74 (see Table 4).

The pH of the water squeezed out of the samples by hand, after the gravitational water was drained off, varied from 4.32 to 5.20, with an average of 4.69.

In all but two samples, C7 and C9, the pH of the water squeezed out was lower than the pH of the gravitational water.

B. Ash content of Samples.

The ash content of samples collected from hummocks varied from 4.76 to 23.2% (of oven dry weight). Within this range samples from eroded hummocks (Sites J and K) varied from 9.48 to 23.2% and the samples from non-eroded hummocks varied from 4.76 to 12.2%.

The ash content of samples collected from hollows (see Table 5) varied from 12.3 to 28.6%.
C. **Ash Alkalinity (Excess Base) of Samples.**

The ash alkalinity of the ashed samples collected from hummock tops varied from 19.4 to 33.0 milliequivalents per 100g. oven dry peat (see Table 5). The values of this property for peats from hollows was 1.57 to 35.9 m.e. per 100g. oven dry peat.

D. **Initial Nitrogen Content of Samples.**

The content of exchangeable (KCl extracted) nitrogen of samples before ammoniation was very low (see Table 6). Two samples from hummock tops had values of 0.020 to 0.024% with an average of 0.022% nitrogen of air dry weight.

Seven samples from hollows had an average of 0.019% nitrogen with a range of 0.012% to 0.027%. One sample, C8, from an eroded hummock at site J had an initial exchangeable nitrogen content of 0.018%. These concentrations were regarded as negligible, being less than 4% of the lowest Kjeldahl nitrogen content of the samples investigated.

E. **Initial Kjeldahl Nitrogen Content of Samples.**

As a percentage of oven dry weight of peat the range for initial Kjeldahl nitrogen was:

- hummocks (except J and K): 0.580 to 1.02%
- hollows: 0.852 to 1.50%
- eroded hummocks (J and K): 0.879 to 1.40%

In Table 6 these values are also given as a percentage of air dry weight and of loss on ignition.
F. Potassium Chloride Extracted Nitrogen Content of Ammoniated Samples.

The amounts of nitrogen extracted from ammoniated samples by potassium chloride solution are listed in Table 7 as percentages of air dry weight, of oven dry weight, and of ignition loss. Ranges of values of this property as a percentage of oven dry weight are:

- hummocks: 0.479 to 1.29%
- hollows: 0.458 to 0.990%
- eroded hummocks: 0.781 to 0.912%

G. Kjeldahl Nitrogen Content of Ammoniated Samples.

In Table 8, are listed the values of Kjeldahl nitrogen from ammoniated peat samples. These values are given as a percentage of oven dry weight, of air dry weight, and of ignition loss weight. Ranges of Kjeldahl nitrogen content from ammoniated samples expressed as a percentage of oven dry weight are:

- hummocks: 1.01 to 1.44%
- hollows: 1.14 to 1.96%
- eroded hummocks: 1.18 to 1.33%

H. Total Nitrogen Content of Ammoniated Samples.

The total nitrogen content extracted from each ammoniated sample is recorded in Table 9 as a percentage of air dry weight and of oven dry weight and as a percentage of ignition loss of peat. Ranges of the total nitrogen content of the ammoniated samples expressed as a percentage of oven dry weight are:

- hummocks: 1.49 to 2.38%
- hollows: 1.59 to 2.93%
I. Fixed Nitrogen in Ammoniated Samples.

The maximum range and average value by the peat samples investigated are listed in Table 10. These are expressed as percentage nitrogen of air dry weight, of oven dry weight, and of ignition loss of peat. The total range of nitrogen fixed by peats of specific topographic locations as a percentage of oven dry weight is:

- hummocks : 0.21 to 0.76%
- hollows : 0.39 to 0.96%
- eroded hummocks : 0.02 to 0.45%
A. Expression of Chemical Concentration

It was thought that to facilitate comparisons of quantitative values of different properties of the samples a common referable property should be selected. The oven dry weight (105° C. for 24 hours) of the peat was chosen for this purpose. Units of concentration were given as a percentage of oven dry weight. Cursory inspection revealed that the concentration is comparable whether the property is expressed in proportion to 100 grams oven dry peat (for example: grams per 100 grams oven dry peat) or as a percentage. Both of these two units of concentration are common in the literature on peat (Waksman and Stevens, 1928a; Mattson and Koutler-Andersson, 1954; Sjörs, 1955; Puustjärvi, 1957; Gorham, 1961). Because in this work, nitrogen content was determined in air dry peat the concentrations were given also as a percentage of air dry weight. Sjörs (1961, page 17) has expressed concentrations of different chemical constituents of peat as a percentage of ignition loss because "loss on ignition represents the content of organic matter fairly well [in 'more', 'mull', and peat]". This method did involve ash determinations which others may not require or obtain. Concentrations have also been given on the basis of percentage of ignition loss but results for individual samples differ little with respect to one another for the different peat samples studied.
B. Evaluation of Procedures.

1. **Preparation of a Uniform Sample.**

   To compare procedures for examination of chemical properties of peat either a sample which will always give reproducible results if the same conditions are applied, or an accepted quantitative reference for these properties is required. Neither is available. The heterogeneity of peat, with respect to many of the chemical properties, often is responsible for the existence of ranges in values which are wider among portions of a single sample than among samples from different locations.

   An attempt was made to prepare a sample of peat, from which sub-samples could be taken, which in turn would give values for nitrogen content that would approach uniformity when analysed under similar conditions. Such a sample was prepared by the sorting and blending technique described in the "Method". Table 1 shows results of seven Kjeldahl analyses representing a precision of more than ninety-nine per cent. The variation was attributed primarily to determinate errors although some indeterminate errors possibly still occur.

2. **Digestion Procedure.**

   Digestion of the Copetown samples was continued for two hours after clearing. This time was chosen on the basis of results obtained for the investigation on the blended peat samples. Because very little difference in concentrations of nitrogen took place between periods of two and three hours of digestion time the shorter period was chosen.
Decreasing by one half the amounts of potassium sulphate and mercuric sulphate used in the Kjeldahl digestions produced no change in the concentration of nitrogen of the blended samples. The smaller concentration was therefore used. The 30 millilitre volume of concentrated sulphuric acid was retained because smaller volumes brought about an increase in problems resulting in frothing and an extension in the digestion time before clearing. Even with this volume of acid, the immersed material tended to force the peat above up into the neck when heat was applied. Larger volumes of acid were not used because of the increased volume of base required to neutralize the acid before distillation.

Modification to include nitro derivations was examined. This involved the use of salicylic acid and sulphuric acid to change the nitro form to the nitrated derivative which was then reduced, by sodium thiosulphate, to an amino derivative, then finally to ammonium sulphate by the sulphuric acid (Willard, Furman and Bricker, 1956). This modification brought about no change in the nitrogen content of the blended samples (Table 2) and was therefore not included in the Kjeldahl digestions of the Copetown samples.

The addition of several drops of 30 per cent hydrogen peroxide, prior to digestion of the peat sample, was continued for the analysis of Copetown samples because it appeared to assist in mechanical breakdown of the peat. No variation in nitrogen concentration resulted from the use of this chemical (see Table 2).
3. **Efficiency of Distillation Apparatus and Procedure.**

The apparatus, as illustrated in Figure 8, was used for all required distillations. It was believed that with the use of this apparatus the flask contents could be make alkaline without any danger of the loss of ammonia. More base or distilled water could be added during distillation to the flask contents without any problem arising. This modification was found to be very useful when serious "bumping" of the contents occurred as distillation was nearing completion. An attempt was made to use a fritted glass gas dispersion tube in place of a glass tube drawn to a fine point. Leggett and Moodie (1962, page 161) emphasized the importance of the use of "multiperforated delivery tubes" in place of "open end tubes". "Small but significant amounts of NH₃ escape sorption by the acid in large bubbles released from an open end delivery tube" (Ibid). With the use of a sintered glass delivery tube a build up of an initial pressure inside the apparatus before the first bubbling occurred either forced apart the individual pieces of the apparatus resulting in a leakage of ammonia or sprayed some of the collecting acid out of the flask with a rapid release of bubbles, thereby ruining the determination.

Efficiency of the distillation procedure was determined by distilling known amounts of ammonium sulphate. Comparison of the results of nitrogen determined by distillation was made with the amount of nitrogen initially present in the dried, weighed sample. Results of this examination were as follows. For a 2.7 x 10⁻³ g. sample of (NH₄)₂SO₄ recovery was 95.73± 0.56% of the weighed sample (two determinations);
for a $20 \times 10^{-3}$ g. sample, recovery was 96.91%; and for a $40 \times 10^{-3}$ g. sample, 98.53%.

Several determinate errors were involved in this investigation. The electric balance used was found to be inaccurate when small portions were extracted from the larger samples. The balance consistently gave heavier readings for these small portions than if they were weighed alone. The distillation apparatus was therefore probably more efficient than the above results indicate. Other determinate errors which would account for the variation are: errors in pipetting and titrating, and loss of ammonia in large bubbles. Because of the doubt of the validity of these results of ammonia sulphate distillations, the values of nitrogen concentrations recorded in the tables were not corrected with the distillation correction factor. This had very little effect on the relative nitrogen concentrations. Consideration was given however when the ranges of nitrogen concentrations of Copetown samples were compared with those of the literature.

4. **Ammoniation**.

Blended samples were ammoniated to obtain some idea of the properties of ammoniated peat, to compare procedures for the extraction of exchangeable ammonia, and to determine ranges in concentrations of fixed ammonia. Ammoniation of blended samples was done using ammonium hydroxide solution because the ammoniating equipment utilizing gases was not operable at that time. This preliminary procedure was not satisfactory because the moisture in the closed jar caused caking of the surface of the peat and controlled proportions of
ammonia to air were not possible. The equipment used for the ammoniation of the Copetown samples overcame these two problems and in addition constantly renewed the gas which was in contact with the peat. Analyses were not made to determine if all the peat in each ammoniating vessel did come in contact with this gas mixture under similar conditions but precautions were taken to prevent packing of the peat in these containers to allow free gas movement.

The accurate determination of rate of flow of gases was not as important with the techniques of nitrogen analysis used here as with methods used by other workers (cf. literature review: Mattson and Koutler-Andersson, 1943; Allison and Roller, 1955). The rate of flow was about 50 litres of air and 5 litres of anhydrous ammonia per hour. The proportion of air to ammonia was therefore 10 to 1. The rate of flow and proportion of gases were reproducible for the ammoniation of all Copetown samples.

Samples of B9 and C6 were ammoniated on July 4 and July 9 respectively. The values of nitrogen concentration of these samples show less variation than the values of nitrogen concentrations of subsamples of B7 which were taken from one ammoniated sample (Table 9). Duplicate values of this property for samples A1, B5, and B12 were determined in the same manner as those of B7. These results tend to discount any variation due to differences in flow rates of gases in the ammoniating apparatus on different days or they show that small variations in flow rates do not affect the fixation of ammonia by these peats.
5. **Ash Alkalinity.**

A problem arose in the back titration of the filtered acid with which the ash had been mixed. During the titration with dilute sodium hydroxide solution a flocculent, white precipitate formed which tended to obscure the first sign of pink of the phenolphthalein indicator. This precipitate formed as neutrality of the mixture was approached (from the acid side). Puustjärvi (1957, page 192) reported that the solution and precipitation of aluminium and iron caused considerable inaccuracy in this method [of Gorham (1953) and the one used by this author]. Puustjärvi (Ibid) recommended that the hydrochloric acid be replaced by "an ammonium acetate buffer solution adjusted to pH 4.5 with HCl. The acidity of pH 4.5 was chosen for the reason that aluminium cannot yet go into solution at this reaction". This modification is recommended for future work on ash alkalinity.

6. **pH Determinations.**

The pH determination of the peat water filtrates were made on a Beckman Zeromatic (electric) pH meter using separate glass and calomel electrodes. Du Rietz (Sjörs, 1950, page 245) reported that "the pH determinations had to be corrected for a salt error which was mainly due to difference in ionic strength (of cations) in the sample and in the comparison buffers". This correction varied with specific electrical conductivities and whether or not calcium was the dominant cation (Ibid). Sjörs (1950, page 246) stated: "It is evident that ±0.3 is the proper correction to apply in strongly acid dilute waters" if proper measurements cannot be taken to determine the exact correction. These measurements of quantitative and qualitative analysis of cation were not available for
the Copetown Bog. The values recorded in Table 4 are not corrected for the "salt error".

7. Addition of Toluene to Fresh Samples.

Less than two millilitres of toluene was added to the fresh samples as they were collected in the field to discourage microbiological activity (Mayboroda, 1961). Waksman and Stevens (1929, page 336) have determined that "the treatment of peat with toluene, even without the removal of the toluene extract, but merely allowing the solvent to evaporate, more than doubled the rate of peat decomposition". The extent of this phenomenon was not investigated in the present work. The volume of toluene used here was quite small in relation to the volume, about 600 cubic centimetres, of peat. Waksman and Stevens did not state the volumes of toluene with which they were concerned. All the fresh samples collected had equal opportunity to decompose with respect to use, both of this chemical and the analytical procedures. The values given for the initial Kjeldahl nitrogen content in Table 6 for sample A4 were obtained in chronological order over a period from May 19 to June 18. Subsamples of A1 examined for initial nitrogen content did show an increase in this property over the period of time from May 19 to July 3 (see Table 6). If the nitrogen content does increase, the loss must be less than the gain of this element. Waksman and Stevens (1928b, page 250) reported that on the drainage of bogs there is a "rapid liberation from peat complexes, of nitrogen, in the form of ammonia". Nikonov and Minkina (1961, page 67) reported: "The intense mineralization of organic substances is not accompanied by any substantial losses of
nitrogen. This increase in nitrogen then could be due to this latter explanation (Ibid) or to possible fixation of ammonia from the air in the laboratory. Because of the small amount of the peat obtained from each site, subsamples were not analysed to determine the extent of ammonia fixation during exposure to the air in the laboratory.

8. Sample Size.

A 2.0 to 2.5 gram amount of dry peat was selected as the appropriate size for analysis in this investigation. Malmer and Sjörs (1955, page 48) stated: "a little more than 2 g. [of peat and fresh plant material] is the desirable minimum for analysis". In the present work the size stated is considered optimum for showing basic trends for purposes of comparisons and yet it is capable of showing diversity of chemical reaction within the peat.

Decreasing sample size decreases precision of duplicates (Sjörs, 1961). Small samples collected side by side at a site, which appears to be uniform in all features, may show as much variation in any of the chemical properties investigated as between samples collected from different sites. This is due to a change in importance of individual physical components of the peat relative to one another. For example, a small woody twig is not as likely to impose its own chemical properties on the total properties in a block of peat in which it represents less than one per cent of the mass than if it is in a very small sample in which it may represent thirty per cent of the mass. The twig is present in both samples but its relative importance is different. This example is particularly pertinent if the nitrogen concentration of the sample is
being investigated.

If larger samples are used, sufficient peat may not be available to make the desired number of analyses. With some of the little decomposed, air dry, mossy peats (especially if they have not been compacted during handling) a two gram amount may represent a sample volume in situ of about 200 cubic centimetres. Not very many samples of this size can be taken from the top of a hummock or from a small patch of Sphagnum sp.

In the present work three - two gram subsamples were required for analyses. One was for initial nitrogen content determination, one was for ammoniation, and one was for ash content and excess base determinations. Even with a sample of this size not all of the desired analyses could be done on each sample, as can be seen from the tables. This is due to losses of samples by frothing during digestion, contamination, and equipment breakdown.

9. Oven Drying of Samples Before Initial Nitrogen Determination.

In Table 3 are recorded the results of analyses of the initial Kjeldahl nitrogen content of peat samples, after these samples had been oven dried at 105° C. in excess of 20 hours. The sample which was prepared by blending peat comprised of Sphagnum sp. showed a loss of weight of 10.4 to 14.5% of the air dry weight. The average weight loss increased with the increased period of heating. The Kjeldahl nitrogen content of these two sets of samples differed. Those heated for 43 hours showed a distinct decrease in this property while those heated for one week showed little change in this property. It is assumed that
those samples heated for one week had lost some nitrogen also in the same amount of time as those heated for 43 hours but this loss must have been compensated for by a gain in nitrogen over this one week period. This replenishment could have come only from the air by way of ammonia fixation by the peat. No further investigation was made into this phenomenon on the basis of fixation in proportion to time.

The two Copetown samples (A2, A3) showed a definite loss of approximately 20 per cent in initial Kjeldahl nitrogen after 21 hours of oven drying.

Unfortunately no chemical investigations are known to have been done of the sample comprised of Sphagnum sp. when it was fresh. Kjeldahl nitrogen content of this blended peat is somewhat below the concentration range of this element for Sphagnum peat samples recorded in the literature (Mattson and Koutler-Andersson, 1943; Gorham, 1961; Sjörs, 1961). A nitrogen loss could have taken place over a period of years. Oven drying may have just accelerated this process in the fresh sample. Kaila et al (1953, page 45) reported that loss of organic matter and of total nitrogen from peat was almost negligible at temperatures below 150° C. They reported that the forms (nitrate-nitrogen, organic-nitrogen, and ammonia) in which nitrogen occurs may vary with temperature but the total nitrogen content remains almost constant. "Heating of moist samples at 75° C for two hours brings about a marked accumulation of ammonia nitrogen. The treatment with dry heat was less effective except when the temperature was raised to 200° C in which case carbonation of peat took place" (Ibid, page 45). "The volatization of ammonia from a medium
more acid than pH 6.5 occurs at a very slow rate" (Ibid, page 41). The peat samples examined had a pH value less than 6.0. In addition "a fairly regular decrease in the pH values with increasing temperature can be demonstrated within the range from 50° to 150°" (Kaila et al., 1953, pages 43-44). In association with this, these workers (Ibid, page 41) point out that "the possible fixation of ammonia.... may deserve some attention".

The results of analysis of initial nitrogen content of peat samples oven dried and recorded in Table 3 appear as contradictions of the work of Kaila et al.

The results obtained in the present work may be anomalies but this could only be determined by analysis of more samples. The occurrence of possible changes in nitrogen concentrations in the peat samples with oven heating led the author to make all nitrogen analyses on air-dried samples.
C. Discussion of Results of:

1. pH Determinations.

The pH values of the gravitational water of the peat samples were somewhat high for an ombrogenous bog. Gorham (1961, pages 104 to 105) reported pH values of an ombrogenous bog peat to be from 3.3 to 4.7 with a mean of 3.8. These results were obtained by direct insertion of a glass electrode into the wet peat. "It should be pointed out that direct insertion of a glass electrode into fresh peat measures not only free acid in solution but also some of the ions adsorbed by peat colloids" (Ibid, page 103). Sjörs (1950, Figure 3, page 250) graphed the ranges in pH which he had found for "different kinds of mire communities". Here he gave normal ranges of pH values as: "mosses 3.7-4.2; extreme poor fens 3.8-5.0; transitional poor fens 4.8-5.7; intermediate fens 5.2-6.4; transitional rich fens 5.8-over 7; extreme rich fens about 7-about 8.4" (Ibid, page 251). Sjörs indicated that "these figures are significant only in North Sweden, and only for determinations made by the same methods" (Ibid).

Two important features of pH analyses of peat for purposes of ecological studies have come forward here. Exact pH correlations with surface vegetation do not exist and different methods of analysis produce different results.

The pH results in Table 4 showed no trend in variation with different times of collection. The "C" samples were collected when the water level was much lower than when the "A" samples were collected. Sjörs (1961) stated that acidity increases as peat dries. Apparently this reaction does not occur with a mere decrease in content of
gravitational water or, if it does, other variations may also occur which obliterate the trend in change.

2. **Ash Determinations.**

The results of ash determinations of peat samples, as recorded in Table 5, showed that peat collected from hollows had a much higher ash content than peat collected from hummocks. This phenomenon has been observed by others (Mattson and Koutler-Andersson, 1954; Malmer and Sjörs, 1955; Gorham, 1961). Gorham (1961, page 104) attributed this variation in ash content between hummocks and hollows to differences in "degree of decay", the peat of the hollows generally being more decayed. This feature was observed for samples collected from the Copetown Bog.

The ash content of peat of Copetown samples, particularly those of hollows, was considerably higher than the range of this property recorded in the literature for ombrogenous bogs (Mattson and Koutler-Andersson, 1954, Table 6 and 8; Sjörs, 1961, Table 4; Gorham, 1961, Tables 1 and 2). These authors reported ash contents in ombrogenous bogs to be less than 9% for hollows and less than 5% for hummocks. Gorham (1961, Table 2) reported mean ash contents as:

- Ombrogenous Sphagnum Bog Peat 3.2% (of dry weight)
- Lacustrine Bog Peat 11.6%
- Reedswamp and Carex Fen Peat 20%

The total determinate errors did not account for much of the variation in ash content which existed between results of the present work and results recorded in the literature.

The ash content of samples taken from Area II revealed another phenomenon. Two completely different classes of peat were found in
very close contact (see "Description of Samples"). The upper layer of peat was greatly decomposed. Sample C1b was composed only of the lower layer of peat. The ash content of this sample approximated that of peat from hollows having little surface vegetation. Samples A3, B1, and B2 were composed of peat from both layers. Graph 1 showed that these samples contained a considerable range of ash content, (from about 12 to 25 grams ash per 100g. peat). Samples collected from any other site did not show this much variation in this property.

The ash content increased with increasing decomposition. Area II had two peats at two different stages of decomposition. The upper peat would therefore be expected to have a low ash content and the lower peat, a high ash content. Mixtures of these two layers in various proportions should have resulted in ash contents which lie between the values of these peats, if each would have been analysed separately. The upper layer of peat was less than one inch thick. Peat which was decomposed very little tended to be very light in weight. The samples were of a size that sufficient peat of the upper layer was not available to form a two gram sample. Because of this, all samples of peat of Area II contained a significant amount of the denser peat of the lower layer. If this was so the peat of the upper layer must have had a very low ash content to have brought about a change from 25 grams (for peat from the lower layer) to 12 grams ash per 100 grams peat. The ash content of the upper layer of peat would then have approximated that of peat collected from tops of hummocks. Wide ranges in concentration were found for initial nitrogen content, ash alkalinity, and Kjeldahl nitrogen content of ammoniated samples indicating the above explanation to have been possible.
The sharp transition from one layer to the other in different properties indicated a sudden change in development from stagnation of growth to rapid growth. This phenomenon was observed at no other place in the bog but it is known not to be uncommon.

3. Ash Alkalinity.

The range of excess base (ash alkalinity) in samples from Copetown Bog agreed very closely with those of Puustjärvi (1957, Table 4) and Mattson and Koutler-Andersson (1954). Results listed in Table 5 showed no clear distinction between values for hummock peat and values of peat from hollows although peat from hollows had an ash alkalinity range which extended below that of hummock tops (see Graph 4). There was also a tendency, for the values of this property, for peats from hummock tops to be grouped together in the approximate middle of the total range. Mattson and Koutler-Andersson (1954, Table 6) gave values of excess base for peats from a hummock top of 13.38 m.e. per 100g. and of a hollow (depression) of 9.52 m.e. per 100g. dry weight. These workers found that peat samples selected at different depths within the hummock had an ash alkalinity content which varied between 8.56 and 13.51 m.e. per 100 grams dry weight. This range was slightly lower than that found in the present investigation. Puustjärvi (1957) reported average values of ash alkalinity for different peat types as:

<table>
<thead>
<tr>
<th>Peat Type</th>
<th>Ash Alkalinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryales - sedge</td>
<td>30.6 m.e. / 100g.</td>
</tr>
<tr>
<td>Eutrophic Sphagnum-Carex</td>
<td>44.8 m.e. / 100g.</td>
</tr>
<tr>
<td>Forest sedge</td>
<td>31.0 m.e. / 100g.</td>
</tr>
<tr>
<td>Carex</td>
<td>16.7 m.e. / 100g.</td>
</tr>
<tr>
<td>Sphagnum-Carex</td>
<td>12.9 m.e. / 100g.</td>
</tr>
<tr>
<td>Carex-Sphagnum</td>
<td>10.7 m.e. / 100g.</td>
</tr>
</tbody>
</table>
This table of results is very difficult to accept if variation with topography of bog surface as great as that found in the present study is not an anomaly. Although some error may have been due to the formation of precipitate during titration (see "Discussion of Methods") in the present work, the values obtained should not be totally disregarded.

4. Initial Kjeldahl Nitrogen Content of Samples.

The range of values for initial nitrogen content of samples from Copetown Bog (Table 6) agreed with that range reported by Mattson and Koutler-Andersson (1954, Table 6), Gorham (1961, Table 1) and Sjörs (1961, Table 4).

Samples from hummock tops had an initial nitrogen content lower than that of samples taken from hollows (Graph 1). Samples taken from the tops of eroded hummocks had values which lie in the region between the ranges of the other two sites. Mattson and Koutler-Andersson (1954), Gorham (1961), and Sjörs (1961) have found similar relationships in this property between peat of hummocks and hollows. (No references have been found in the literature for eroded hummocks.) This relationship is attributed to the fact that hummock peat is usually less decomposed (Gorham, 1961). Nitrogen contents were reported lowest under "regenerating Sphagnum" (Ibid, page 106). The results of the present work tended to support this. Site C had the most luxurious growth of Sphagnum sp. and its initial nitrogen content was relatively high. This however was due to the inclusion of more decomposed peat below the Sphagnum sp. peat.
High initial nitrogen content is "an expression of stagnation of growth" (Mattson and Koutler-Andersson, 1954, page 357). In this investigation highest initial nitrogen contents were found in hollows having little or no living vegetation surface cover, thereby supporting Mattson's explanation.

5. Nitrogen Content of Ammoniated Samples.

Although Mattson and Koutler-Andersson (1954) investigated the amounts of total nitrogen and fixed ammonia in ammoniated samples of peat taken from a profile of the Ramna Bog, no references could be found in the literature for these properties of peat samples collected from the surface of a bog. Comparison of results of investigation of these properties of peat collected from hummocks and hollows, in this study, with the results of others is therefore not possible.

From Mattson and Koutler-Andersson's results (1954, Table 3) ranges of properties of ammoniated peat can be obtained. They found that total nitrogen (after ammoniation) varied from 2.65 to 4.83% nitrogen of organic matter. Total nitrogen of ammoniated samples taken from Copetown Bog varied from 1.68 to 4.11% nitrogen of matter lost during ignition (ignition loss) (Table 9). Using the wet ammoniation method, Mattson and Koutler-Andersson (Ibid) found concentrations of fixed nitrogen to have been from 1.17 (near the surface) to 3.92% nitrogen of organic matter. Their lower concentration had about 0.3% nitrogen more than the highest found in samples from the Copetown Bog. This difference in concentrations may have been due to differences in methods of ammoniation. These authors reported (Ibid, 1943) that "ammonia fixation amounted to 4.00% nitrogen by the wet method and 3.44% by the dry method" for a
particular sample being investigated. Although their "dry method" of ammoniation was quite different from that used here, the resulting difference in amount of ammonia may still apply. No comparison was made for samples of lower nitrogen concentration so that the difference in fixed nitrogen between Copetown samples and those of Mattson and Koutler-Andersson's (1954) work could be due either to differences in ammoniating technique or differences due to the peat itself.

Results of potassium chloride solution extracts of ammoniated samples showed the concentrations of this exchangeable ammonia to be approximately equal (Table 7) irrespective of sample location. No correlation could be found between the variations in concentration of exchangeable ammonia and any other property investigated of these samples. Ranges in concentrations of Kjeldahl nitrogen of the ammoniated samples differed for peat from hummock and hollow (Table 8). Ammoniated peats taken from hollows contained larger amounts of Kjeldahl nitrogen than ammoniated peats from hummocks. Samples from eroded hummocks differed little from those of other hummocks with respect to values of this property.

Peat collected from hollows tended to fix more ammonia than peats from hummocks (Table 10). Peat from eroded hummocks fixed the least amount of ammonia. This phenomenon was clearest if per cent nitrogen of ignition loss was examined. In this way the nitrogen was expressed essentially as a percentage of organic matter.
D. Correlation of Nitrogen Content of Ammoniated Samples with Other Properties Investigated.

Values in Graph 3 indicated an approximation to linear correlation between ash content and Kjeldahl nitrogen of ammoniated samples exists. Linear correlation was more nearly approached between the initial Kjeldahl nitrogen content and the ash content of the peat samples investigated (Graph 1). The slopes of these two lines were very similar. The position of these lines was selected visually.

Analysis of Graph 3 showed that all samples of peat did not have the same potential for fixing ammonia although samples from specific locations designated by topography tended to group together. The presence of these groups of values suggested that a topographic factor was associated with chemical properties of the peat.

Graph 1 showed closer correlation of nitrogen content with ash content for peat from hummocks than for peat from hollows. This result combined with the unusually high ash content could have been attained through influence of wind erosion of the surrounding fields and subsequent settlement of the wind-borne matter onto the surface of the bog. In spite of this high ash content, correlation between ash content and nitrogen content was not lost. The addition of this wind-borne matter to the bog surface was likely to have less effect on the ash content of peat from hummocks than from hollows because there was more opportunity for the particles to have been washed off the hummocks into the hollows. Here it tended to accumulate. This substantiates Sjörs' (1948) findings that vertical water movement occurred less in hollows than in hummocks. Lateral surface movement of water was believed to have
been negligible except perhaps during flooding. Very little ash therefore would have been distributed very far laterally on the surface of the bog.

Ash content was not as closely correlated with Kjeldahl nitrogen content of ammoniated peat as it was with initial Kjeldahl nitrogen content (refer to Graphs 1 and 3). This was most obvious with peat from hummocks. Not only was the proximity of the values to the regression line decreased but considerable horizontal rearrangement of points relative to one another has occurred for values of peat from hummocks. Rearrangement has not occurred to the same extent for values of peat from hollows. Determination of ash content was of less value for prediction of total potential nitrogen content for peat from hummocks than for peat from hollows. In contrast, ash content analysis did enable one to make closer predictions of the initial nitrogen content of peat from hummocks than of peat from hollows.

Koutler-Andersson (1960, page 35) emphasized that "a distinct negative correlation between total nitrogen and excess base in ash" was characteristic of bog profiles, with some exceptions, especially in the upper part of the profiles. Graph 4 showed that a possible inverse relationship between ash alkalinity and total nitrogen of the ammoniated sample may exist for peat near the surface but until more values are available conclusion on this point is tentative.

E. Comparisons of Selected Properties of Peat From Hummocks and Hollows.

Many have examined certain aspects of hummock-hollow association in bogs (Kulczynski, 1949; Mattson and Koutler-Andersson, 1954; Sjörs, 1949, 1961; Gorham, 1961; and others). Kulczynski (1949) reported that
R. Sernander and L. von Post were the first to propose the "lenticular regeneration of *Sphagnum* peat". H. Osvald extended this idea and developed a theory concerning the "regeneration complex" which joins together associations of the raised bog into an "association complex". Kulczynski (1949, page 67) stated: "Today the theory of the lenticular regeneration of *Sphagnum* peat stands among the most beautiful and well grounded achievements of bog science".

Basically this hummock-hollow regeneration cycle involves development of two ecologically diverse *Sphagnum* types — (1) the hydrophilous *Sphagna* and (2) the semiterrestrial *Sphagna* — and the changes they bring about enabling other plants to develop. Osvald [reported by Mattson and Koutler-Andersson (1954, page 356)] describes, with reference to species, the development of vegetation beginning in a wet depression and ending in a fully developed hummock. Osvald (Ibid) continues:

"After the hummock has grown to a certain height it gets too dry for the mosses which dry out and are replaced by heather and lichen. But then the growth is inhibited, and as the surrounding parts simultaneously grow in height a day will eventually come when the former hummock is drowned, heather and lichen rot away and their place in the wet depression is again invaded by *Sphagnum cuspidatum*. A new cycle has started."

The role of each species and associations of species has been studied in this sequence (Kulczynski, 1949; Mattson and Koutler-Andersson, 1954; Gimingham *et al.*, 1961). Chemical analyses of certain properties of peat have been studied in hummocks and hollows (Mattson and Koutler-Andersson, 1954; Sjörs, 1949, 1961; Gorham, 1961). In agreement with
the results of these workers, the results of this investigation of the properties selected do show a difference in ranges of values of peat of hummocks and of hollows. These properties which have distinct ranges are: initial nitrogen content, total and Kjeldahl nitrogen content, and ash content. No differences were found to exist between peat of hummocks and hollows in loss of weight on oven drying, ash alkalinity, and exchangeable ammonia. Although there is considerable overlap of ranges, the concentration of fixed ammonia may differ for peat of hollows and hummocks.

The higher nitrogen and ash contents of the hollows indicate that there is a stagnation of growth. The initial nitrogen content is believed to be higher than that of peat from hummocks because the hollows contain more peat which is more humified or decomposed. As humification occurs all plant remains do not break down at the same rate. Lignin being a more resistant compound, tends to increase in proportion to the total organic matter. Mattson and Koutler-Andersson (1943, 1954) stated that lignin is not the only component which is capable of fixing ammonia but it is one of the most important. Therefore, relative increases in lignin in peat lead to an increase in the initial nitrogen content which is expressed as a percentage nitrogen of peat weight. Comparison of the results listed in Table 6 with assessed von Post Humification numbers supports this explanation. Further evidence is that total nitrogen after ammoniation varies with the state of the peat.

The amount of nitrogen fixed by peat collected from eroded hummocks encourages speculation. The initial Kjeldahl nitrogen content
of this peat falls within the range of values for this property of peat from hollows. The total nitrogen content of ammoniated peat of eroded hummocks lies within the range of values for this property of peat from hummocks. From this it appears that the ammonia fixing constituents of peat from eroded hummocks differ little from those of less decomposed peat from non-eroded hummocks. The author believes that peat from the eroded hummocks investigated has a higher initial nitrogen content because this peat is more exposed to the atmosphere. The eroded hummocks have surface vegetation which is less dense and luxurious and they have peat which has a looser, crumbly structure than non-eroded hummocks. The eroded hummocks tend to be drier on top probably because of the breakdown on fine capillaries with the development of a coarser structure. These features very likely allow for freer movement of air in and out of eroded hummocks than of non-eroded hummocks. Some samples from eroded hummocks fixed little or no ammonia during ammoniation, possibly because they had already effected fixation to their capacity. A longer period of ammoniation then would have brought about no further change in the final nitrogen content.

The peat from these eroded hummocks are more decomposed than peat from non-eroded hummocks but are less decomposed than the peat of most hollows. If ammonia fixation increases as decomposition of peat increases the peat of eroded hummocks should be expected to have a total nitrogen content after ammoniation which is somewhere between the values of this property for peat of hummocks and that for peat of hollows. This does not occur. To account for this phenomenon one could believe that either the ammonia fixing constituents have not increased
yet in relative importance or that some of the ammonia fixing constituents have been lost during decomposition.

In addition, the very wide range of values of initial nitrogen content and ash content of these samples is somewhat confusing because there does not appear to be a wide range of decomposed peat present. A possible answer arises after an examination of Tables 6 and 9. Sites L and M were hollows immediately adjacent to the eroded hummocks of sites I and J. Peat from sites L and M, particularly M, has an initial nitrogen content which is among the highest found. Peat from these two hollows had the highest nitrogen content after ammoniation. In addition they had a very high ash content. It is possible that a constituent of peat which is capable of fixing ammonia has moved from the tops of the eroding hummocks down into the nearby hollow, perhaps under the influence of moisture during precipitation. The exact substance is not known but is probably either small solid particles or a water-soluble substance. The latter is possible because Mattson and Koutler-Andersson (1943) reported water soluble matter in peat which was capable of fixing ammonia. If the substance was soluble it would be leached out of all hummocks and into the hollows. The end result would be an inverse correlation between peat of hummocks and peat of nearby hollows with respect to ammonia fixing capabilities. This was not found. This substance must therefore become mobile after decomposition of peat reaches a more advanced stage.

The very high ash content of peat of site M cannot be attributed to wind blown matter because this site was very near the middle of the
bog. Neither surface courses nor vertical movements of mineralized water is apparent in this area. The only likely source then is mineral matter washed out of the nearby eroded hummock. This mineral matter would become mobile during mineralization of organic material of the hummock. This lends support to the view that the nitrogen fixing substance may be released in greater proportions during peat decomposition.

Another phenomenon characterized by peat from sites L and M is their very low concentration of excess base (ash alkalinity). The base-binding capacity of peat was reported to a very inversely with nitrogen content and with huminosity (Mattson and Koutler-Andersson, 1954). The peat from these sites illustrates this inter-dependency very well for here the highest initial nitrogen contents and lowest concentrations of excess base were encountered.

The possibility of the above described and explained changes of properties of peat, during the dying and erosion of a hummock, being an anomaly due to analytical errors is poor. The inter-dependency of the investigated properties of peat still exists for peat from eroded hummocks.

F. Implications Arising From Results.

Ranges of values are considered to be more reliable than specific values where chemical constitution of peat is involved. Averages of certain properties of peat of specific sites designated by topographic location are useful for approximations, but knowledge of the range of values for the pertinent property provides the context of reference.

Thus, Graphs 1, 2, 3, and 4 can be used for determining approximations of values. This is done by determining the equation of the
regression line, (for example the equation for this line in Graph 1 is; 
\[ \text{Ash content} = 24 \text{ (Initial nitrogen content)} - 9.8 \]), and substituting a 
value for one of the unknown properties and solving the equation for the 
other. The resulting value for this property is an approximation but 
it is likely to be close enough to the possible value to determine at 
least whether the sample came from a hummock or a hollow.

With a material as heterogeneous as peat, for the chemical 
properties investigated, and very likely for some others, application 
of statistics could be difficult and dangerous. Sjörs (1950, page 242), 
after examining concentrations of dissolved salts, emphasized: "Even 
if it were possible to obtain statistically good results by some method, 
some rare but interesting combination of [water] conditions might be 
overlooked". In conjunction with this, samples of peat which appear to 
be outliers should not be discarded for the sake of procuring better 
approximations. The worker must be aware these samples do exist and they 
really may not be anomalies.

Because of the tedious and time consuming processes involved in 
the study of cores of profiles of a bog, there is a tendency to examine 
only one core per bog and to base all conclusions and predictions on the 
results obtained from that core. The variations in results obtained in 
the present investigation readily show a shortcoming of the single core 
investigation. Here values of some of the properties have doubled within 
a lateral distance of just one foot. No reason is known why this 
variation would be completely destroyed as depth of samples in the bog 
increases. As long as peat retains its heterogeneity, and the present 
work shows how difficult it is to prepare a homogeneous sample, no
possible prediction can be made for changes in vegetation and certain chemical properties with respect to time and peat deposition which could apply to the entire bog. At the most only the sequence of events for that site, which have been recorded in the core examined, can be ascertained.

The results of the present investigation also indicate that the use of an average value of a certain property to represent the conditions existing for that property in a specific type of bog is of little practical use. Averaging the results of hummocks and hollows together of most of the individual properties investigated in the present study merely gives a hypothetical concentration for this property and says little about the conditions which exist in the bog at this time.

Peat may be heterogeneous but the diversity of concentrations of certain properties can still be handled to obtain useful and meaningful results if approximate ranges are determined and if changes in influence of relative components with changing sample size is recognized and considered. (This was illustrated previously with the example of a woody twig in a block of peat composed mostly of a moss).

Results of this work lend further evidence to the argument that hummocks and hollows are real identities having their own chemical properties in addition to their own plant associations. It is possible then that other visible topographic features of bogs have chemical characteristics specific for them. Investigation of these other features from this aspect may lead not only to a better knowledge of their distribution, but also to factors which affect the initiation and conclusion of their existence. The author wishes to caution the reader that although specific ranges of chemical characteristics exist for
topographic features there is no reason to suppose that any single factor should determine the differentiation of these features. This differential is very likely the result of co-variation of several factors.

The author is aware of some of the problems of microbiological activity in bogs and the effect on changes in certain properties of peat and of the restrictions certain properties of peat impose on the activity of microorganisms and development of higher plants, but examination and discussion of this has not been considered an integral part of the present investigation although it may prove worthy of study in the light of the results of the present work.
SUMMARY AND CONCLUSIONS

To compare methods of analysis of initial nitrogen content a sample of peat, which was almost uniform in this property, was required. A sample of sufficient uniformity was prepared by a sorting and blending technique. Methods shown to be satisfactory by the use of this blended peat presented few problems when used on fresh samples.

Before assessment of the phenomenon of ammonia fixation could be made properties initially present in the peat were examined. The air dry samples investigated contained very little exchangeable nitrogen. Although the concentration of this property was not uniform, it did not vary with any of the other properties investigated. A wide range in concentration of the initial Kjeldahl nitrogen content was found with the values of peat from hummocks being lower than those of hollows. The values of this property for peat from eroded hummocks extended, with some overlap, from the values of initial nitrogen content of non-eroded hummocks to those of hollows. Subsamples taken from a sample collected from any of the sites investigated varied as much in initial Kjeldahl nitrogen content as samples collected from the same site at different times.

Peat collected from the hollows investigated was characterized by a range in ash content which was higher than that of peat from the hummocks investigated. The range of amounts of ash content of peat from eroded hummocks extended, with some overlap, from the lower to the higher range of values of the other two site types.
The values of pH of gravitational water and of water squeezed from the sample were high for ombrogenous bogs and they varied with none of the other properties investigated. In all but two samples the gravitational water had a lower pH than the water squeezed from the sample.

The range ash alkalinity content of the samples investigated was greater than that recorded in the literature for ombrogenous bogs.

The results of the present work have substantiated the reported phenomenon that ammonia is absorbed and fixed to some extent by peat. Results indicated that ammonia from the atmosphere may have been fixed by the peat samples while they were air drying. Gaseous ammonia, in concentrations greater than in the atmosphere, was fixed by peat during ammoniation. The degree of ammonia fixation was governed by the amount of ammonia previously fixed, the total potential of the peat for ammonia fixation, and the amount of ammonia available. All peat did not have the same potential for fixation of ammonia.

That ammonia which was not removed from the peat by water washings but was removed by 1 M. potassium chloride solution was defined as exchangeable ammonia. The exchangeable ammonia content varied, but in no predictable manner, with the samples investigated.

The concentration of total nitrogen after ammoniation tended to be higher for peat from hollows than for peat from hummocks. The concentration of this nitrogen in peat from eroded hummocks differed little from that of peat from non-eroded hummocks.
Peat from hollows tended to fix more ammonia than peat from non-eroded hummocks. Peat from eroded hummocks fixed the least amount of ammonia and some of this peat fixed no ammonia at all during ammoniation. It is possible that peat from eroded hummocks had fixed atmospheric ammonia almost to their full potential while they were still in situ. This was possible because of the greater air movement possible in the loose structure of peat of eroded hummocks than in the vegetation-covered, non-eroded hummocks and the water-soaked, denser peat of hollows.

The concentration of ammonia fixed during ammoniation was always less than the amount of nitrogen initially present and was also less than the amount of exchangeable ammonia, for each sample investigated.

Correlation has been found between nitrogen content of peat, before and after ammoniation, with certain other properties of the peat investigated.

Peat collected from both hummocks and hollows was characterized by a straight line relationship between the initial Kjeldahl nitrogen content and the ash content of the samples and also between initial Kjeldahl nitrogen content and Kjeldahl nitrogen content after ammoniation. This was supported by an approximation to a straight line relationship between Kjeldahl nitrogen content of the ammoniated sample and ash content of the samples. Here then were three properties which varied together. Approximations of the concentration of any one of these properties could be made if values of any of the other two properties and the equation of the regression line are known.
There was evidence in the present work to suspect that total nitrogen content of the ammoniated sample may have varied inversely with the ash alkalinity. This relationship has been observed in peat profiles of bogs by others.

Analysis of results of the present investigation has suggested that phenomena related to the properties studied have occurred.

The ash content of peat of both hummocks and hollows has been found to be considerably higher than that found in the literature for ombrogenous bogs. This increased ash content was attributed to a settling of wind-borne mineral matter onto the surface of the bog. This should be considered in areas where much cultivation is common. In spite of this high ash content the relationship between total nitrogen content and ash content of the peat was still present.

There appeared to be an accumulation of substances, capable of fixing ammonia, and of mineral matter in hollows, particularly those near eroded hummocks. Water movement was the most likely method of transportation of these substances. This tended to substantiate the claim of Sjörs that water movement is more extensive in hummocks than in hollows.

Results have shown that although peat is heterogeneous, with respect to the properties investigated, fairly distinct ranges of concentrations of these properties existed and were characteristic of peat of both hummocks and hollows. This then was further evidence that hummocks and hollows are real entities having their own chemical characteristics as well as having their own plant associations.
Averages of any of the properties investigated are useful and meaningful only if they are considered in context with the ranges in concentrations of these properties. Neglection of these ranges is neglection of the presence of the heterogeneity of peat with respect to certain properties. In light of this, use of results, obtained from single core analysis, to explain past conditions and general development of the bog as a whole is subject to serious error. For the same reason representation of a certain property of an entire bog by an average value is not likely to be of much value for depicting the actual conditions existing in the bog at that time. Because statistics very often involves the establishment of means and averages, attempts to enforce its use may lead to serious errors by causing the worker to overlook unusual situations which may arise.
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Figure 1.

Vertical aerial photograph of Copetown Bog. Highway 52 skirts the western boundary and the T.H. & B. R.R. the eastern boundary of the bog. Sample areas are marked by X. Enlarged photograph was made from R.C.A.F. aerial photograph #60134-82 obtained from the Wentworth Planning Board, Hamilton.

Scale: lin.: 240 ft.
Figure 2.

View of the general region around area II in Copetown Bog. Photograph taken from embankment of Highway 52 facing south-east. Vegetation in foreground is D of the lagg, middle ground is EFI-FEI, background is BEF-BFE.
Figure 3.
Area I, EFI-FEI in foreground and middle ground. Photograph taken towards south-east.
Figure 4.

Area II, EFI-FEI, in foreground. Photograph taken towards east-south-east.
Figure 5.
Area III, BEF-BFE, in fore and middle ground. Photograph taken towards north-north-east.
Figure 6.

Area IV, BEI, in middle ground. Photograph taken towards east-south-east.
Figure 7.

Area V, BEI. Photograph taken towards north-east.
Figure 8.

DIAGRAM OF DISTILLATION APPARATUS
Figure 9.

DIAGRAM SHOWING SEQUENCE OF APPARATUS USED
FOR AMMONIATING SAMPLES OF PEAT

1. Compressed air tank fitted with gauges and valves (Matheson of
   Canada Ltd.).
2. Tank of anhydrous ammonia with Regulator No. 12-240 check valve,
   and line needle valve (Matheson of Canada Ltd.).
3. Pyrex Flowmeters, model 5960 (Corning Glass Works).
4. "U" tube manometers, 3mm. outside diameter.
5. Sample container(s), 3 to 5 connected in series with entry tube
   near bottom and outlet tube at the top of each container (Pyrex
   test tubes 290 x 30 mm.), or a single 250 ml. Erlenmeyer flask.
6. Constant temperature bath containing about 0.07 m$^3$ of water. The
   tank was insulated with styrofoam sheets on all surfaces. A
   Precision Scientific Company "Porta-Temp" was used to circulate
   and maintain the temperature of the water at 27.0$^\circ$ 0.1$^\circ$C.
7. Container of dilute acid used to trap the ammonia at the end of
   the gas line.
TABLE 1.

The Effect of Duration of Digestion After Clearing on Kjeldahl Nitrogen Content of Blended Sphagnum sp. Peat Sample.

<table>
<thead>
<tr>
<th>Number of hours after clearing digestion continued</th>
<th>Kjeldahl Nitrogen content as a percentage of air dry weight of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.440</td>
</tr>
<tr>
<td>2</td>
<td>0.439</td>
</tr>
<tr>
<td>2</td>
<td>0.445</td>
</tr>
<tr>
<td>3</td>
<td>0.438</td>
</tr>
<tr>
<td>3</td>
<td>0.444</td>
</tr>
<tr>
<td>3</td>
<td>0.448</td>
</tr>
<tr>
<td>3</td>
<td>0.438</td>
</tr>
</tbody>
</table>

Average value for 2 hour period: 0.441%
Average value for 3 hour period: 0.442%
TABLE 2.

Effect of Variation of Digestion Period For Time After Clearing, Addition of 30% H₂O₂, and Inclusion of Nitro derivatives on Initial Kjeldahl Nitrogen Content of the Blended Sphagnum sp. Peat Sample

<table>
<thead>
<tr>
<th></th>
<th>Nitro Derivatives Included</th>
<th>Nitro Derivatives Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 hour</td>
<td>3 hours</td>
</tr>
<tr>
<td>Addition of H₂O₂</td>
<td>0.443</td>
<td>0.442</td>
</tr>
<tr>
<td>Exclusion of H₂O₂</td>
<td>0.442</td>
<td>0.444</td>
</tr>
</tbody>
</table>

Nitrogen content as a percentage of air dry weight of peat sample.
TABLE 3.
Effect of Oven Drying the Sample at 105°C on the Initial Kjeldahl Nitrogen Content

<table>
<thead>
<tr>
<th>Sample</th>
<th>Period of Oven Drying</th>
<th>Oven Dry wt. as a percentage of Air Dry wt.</th>
<th>N° Kjeldahl as a percentage of Oven Dry wt.</th>
<th>N° Kjeldahl as a percentage of Air Dry wt.</th>
<th>N° Kjeldahl of unheated samples.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blended Sphagnum sp. Peat</td>
<td>43 hr.</td>
<td>89.6</td>
<td>0.433</td>
<td>0.388</td>
<td></td>
</tr>
<tr>
<td></td>
<td>43 hr.</td>
<td>86.6</td>
<td>0.450</td>
<td>0.346</td>
<td>0.441</td>
</tr>
<tr>
<td></td>
<td>1 week</td>
<td>87.6</td>
<td>0.526</td>
<td>0.460</td>
<td>+0.02%</td>
</tr>
<tr>
<td></td>
<td>1 week</td>
<td>85.5</td>
<td>0.506</td>
<td>0.433</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>86.6</td>
<td>0.479</td>
<td>0.409</td>
<td>0.441</td>
</tr>
<tr>
<td>A2</td>
<td>21 hr.</td>
<td>80.2</td>
<td>0.897</td>
<td>0.719</td>
<td>1.08</td>
</tr>
<tr>
<td>A3</td>
<td>21 hr.</td>
<td>80.9</td>
<td>0.934</td>
<td>0.756</td>
<td>0.965</td>
</tr>
</tbody>
</table>
TABLE 4.

pH of Water from Samples.

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample</th>
<th>pH of Gravitational Water</th>
<th>pH of water squeezed out of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>B4</td>
<td>4.80</td>
<td>4.59</td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>5.00</td>
<td>4.79</td>
</tr>
<tr>
<td>C</td>
<td>A3</td>
<td>5.35</td>
<td>4.83</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>4.60</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>4.90</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>C1</td>
<td>4.89</td>
<td>4.70</td>
</tr>
<tr>
<td>E</td>
<td>B7</td>
<td>4.53</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>C4</td>
<td>4.63</td>
<td>4.57</td>
</tr>
<tr>
<td>G</td>
<td>B5</td>
<td>4.53</td>
<td>----</td>
</tr>
<tr>
<td>H</td>
<td>C12</td>
<td>4.50</td>
<td>4.32</td>
</tr>
<tr>
<td>L</td>
<td>B10</td>
<td>4.37</td>
<td>----</td>
</tr>
<tr>
<td>M</td>
<td>B11</td>
<td>4.98</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>C7</td>
<td>4.99</td>
<td>5.20</td>
</tr>
<tr>
<td>N</td>
<td>C9</td>
<td>4.30</td>
<td>4.48</td>
</tr>
</tbody>
</table>
### TABLE 5.
Ash Content and Ash Alkalinity of Peat Samples

<table>
<thead>
<tr>
<th>Area</th>
<th>Site</th>
<th>Topography and Sample Number</th>
<th>Weight of Ash grams 100g.</th>
<th>Ash Alkalinity as milliequivalents per 100g. Oven Dry Weight of Peat at (105°C, 24 hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I A</td>
<td>hummock</td>
<td>A1</td>
<td>6.67°</td>
<td>-----</td>
</tr>
<tr>
<td>I B</td>
<td>hollow</td>
<td>B3</td>
<td>5.43</td>
<td>19.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>7.90</td>
<td>33.0</td>
</tr>
<tr>
<td>II C</td>
<td>hollow</td>
<td>A3</td>
<td>14.1°°</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B1</td>
<td>12.3</td>
<td>35.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B2</td>
<td>15.9</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B1b</td>
<td>25.3</td>
<td>10.4</td>
</tr>
<tr>
<td>III D</td>
<td>hummock top</td>
<td>A4</td>
<td>12.2°°</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B3</td>
<td>12.2°°</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C5</td>
<td>12.2°°</td>
<td>-----</td>
</tr>
<tr>
<td>III E</td>
<td>hollow</td>
<td>B7</td>
<td>18.9°°</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C4</td>
<td>15.0°°</td>
<td>12.5</td>
</tr>
<tr>
<td>IV F</td>
<td>hummock top</td>
<td>B6</td>
<td>4.76°°</td>
<td>18.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C11</td>
<td>4.76°°</td>
<td>-----</td>
</tr>
<tr>
<td>IV G</td>
<td>hollow</td>
<td>B5</td>
<td>18.9°°</td>
<td>10.5</td>
</tr>
<tr>
<td>IV H</td>
<td>hollow</td>
<td>C12</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>V I</td>
<td>hummock top</td>
<td>B9</td>
<td>5.60°°</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C6</td>
<td>7.26°°</td>
<td>17.4</td>
</tr>
<tr>
<td>V J</td>
<td>hummock top</td>
<td>B12</td>
<td>9.48°°</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C8</td>
<td>17.9°°</td>
<td>24.6</td>
</tr>
<tr>
<td>V K</td>
<td>hummock top</td>
<td>C10</td>
<td>23.2°°</td>
<td>15.7</td>
</tr>
<tr>
<td>V L</td>
<td>hollow</td>
<td>B10</td>
<td>22.8°°</td>
<td>4.56</td>
</tr>
<tr>
<td>V M</td>
<td>hollow</td>
<td>B11</td>
<td>28.6°°</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C7</td>
<td>28.6°°</td>
<td>-----</td>
</tr>
<tr>
<td>V N</td>
<td>hollow</td>
<td>C9</td>
<td>18.0°°</td>
<td>5.52</td>
</tr>
</tbody>
</table>

* indicates sample not ashed, value calculated from average of others at that site.

**°° value is an average of B1 and B2; C1b not included in average.

----- indicates value not obtained.
TABLE 6.
Nitrogen Extracted from Peat Samples by Kjeldahl Digestion (N° Kjeldahl) Before Ammoniation.

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample</th>
<th>N° Kjeldahl as a Percentage of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Air Dry Weight</td>
</tr>
<tr>
<td>A</td>
<td>A1</td>
<td>0.581</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.645</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.681</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>0.525</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>0.697</td>
</tr>
<tr>
<td>B</td>
<td>A2</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>B4</td>
<td>0.922</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.870</td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>1.03</td>
</tr>
<tr>
<td>C</td>
<td>A3</td>
<td>0.905</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>0.797</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>0.756</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>C1</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.876</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.01</td>
</tr>
<tr>
<td>D</td>
<td>A4</td>
<td>0.693</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.647</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.737</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.640</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>0.609</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.891</td>
</tr>
<tr>
<td></td>
<td>C5</td>
<td>0.903</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.789</td>
</tr>
<tr>
<td>E</td>
<td>B7</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.20</td>
</tr>
<tr>
<td>F</td>
<td>B6</td>
<td>0.524</td>
</tr>
<tr>
<td></td>
<td>C11</td>
<td>0.554</td>
</tr>
<tr>
<td>G</td>
<td>B5</td>
<td>0.928</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.998</td>
</tr>
<tr>
<td>H</td>
<td>C12</td>
<td>0.932</td>
</tr>
<tr>
<td>I</td>
<td>B9</td>
<td>0.615</td>
</tr>
<tr>
<td></td>
<td>C6</td>
<td>0.697</td>
</tr>
<tr>
<td>J</td>
<td>B12</td>
<td>0.803</td>
</tr>
<tr>
<td></td>
<td>C8</td>
<td>1.01</td>
</tr>
<tr>
<td>K</td>
<td>C10</td>
<td>1.33</td>
</tr>
<tr>
<td>L</td>
<td>B10</td>
<td>1.07</td>
</tr>
<tr>
<td>M</td>
<td>B11</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>C7</td>
<td>1.34</td>
</tr>
<tr>
<td>N</td>
<td>C9</td>
<td>1.13</td>
</tr>
</tbody>
</table>
TABLE 7.

Nitrogen Extracted from Ammoniated Peat Samples by KCl Solution ($N_{KCl}^A$)

<table>
<thead>
<tr>
<th>Site Sample</th>
<th>Air Dry Weight</th>
<th>Oven Dry Weight</th>
<th>Ignition Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>A A1</td>
<td>0.447</td>
<td>0.479</td>
<td>0.543</td>
</tr>
<tr>
<td></td>
<td>0.561</td>
<td>0.553</td>
<td>0.627</td>
</tr>
<tr>
<td>B3</td>
<td>0.843</td>
<td>0.956</td>
<td>1.02</td>
</tr>
<tr>
<td>B</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>C B1</td>
<td>0.407</td>
<td>0.458</td>
<td>0.522</td>
</tr>
<tr>
<td>B2</td>
<td>0.541</td>
<td>0.670</td>
<td>0.796</td>
</tr>
<tr>
<td>D A4</td>
<td>0.875</td>
<td>0.999</td>
<td>1.14</td>
</tr>
<tr>
<td>B8</td>
<td>0.700</td>
<td>0.799</td>
<td>0.911</td>
</tr>
<tr>
<td></td>
<td>0.747</td>
<td>0.852</td>
<td>0.971</td>
</tr>
<tr>
<td>E B7</td>
<td>0.661</td>
<td>0.735</td>
<td>0.906</td>
</tr>
<tr>
<td></td>
<td>0.733</td>
<td>0.815</td>
<td>1.00</td>
</tr>
<tr>
<td>F B6</td>
<td>1.17</td>
<td>1.29</td>
<td>1.36</td>
</tr>
<tr>
<td>G B5</td>
<td>0.776</td>
<td>0.841</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>0.663</td>
<td>0.718</td>
<td>0.885</td>
</tr>
<tr>
<td>H</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>I B9</td>
<td>0.671</td>
<td>0.738</td>
<td>0.782</td>
</tr>
<tr>
<td>C6</td>
<td>0.845</td>
<td>0.930</td>
<td>1.02</td>
</tr>
<tr>
<td>J B12</td>
<td>0.714</td>
<td>0.781</td>
<td>0.863</td>
</tr>
<tr>
<td></td>
<td>0.834</td>
<td>0.912</td>
<td>1.01</td>
</tr>
<tr>
<td>K</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>L B10</td>
<td>0.758</td>
<td>0.817</td>
<td>1.06</td>
</tr>
<tr>
<td>M B11</td>
<td>0.888</td>
<td>0.990</td>
<td>1.09</td>
</tr>
<tr>
<td>N</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
</tbody>
</table>
TABLE 8.
Nitrogen Extracted from Ammoniated Peat Samples by Kjeldahl Digestion. (following aqueous and KCl solution extractions). (N\textsuperscript{A} Kjeldahl)

<table>
<thead>
<tr>
<th>Site Sample</th>
<th>Air Dry Weight</th>
<th>Oven Dry Weight</th>
<th>Ignition Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>A A1</td>
<td>0.94</td>
<td>1.01</td>
<td>1.14</td>
</tr>
<tr>
<td>B3</td>
<td>1.03</td>
<td>1.10</td>
<td>1.25</td>
</tr>
<tr>
<td>B</td>
<td>1.16</td>
<td>1.31</td>
<td>1.40</td>
</tr>
<tr>
<td>C B1</td>
<td>1.01</td>
<td>1.14</td>
<td>1.30</td>
</tr>
<tr>
<td>B2</td>
<td>1.47</td>
<td>1.81</td>
<td>2.15</td>
</tr>
<tr>
<td>D A4</td>
<td>1.12</td>
<td>1.28</td>
<td>1.45</td>
</tr>
<tr>
<td>B8</td>
<td>1.22</td>
<td>1.40</td>
<td>1.59</td>
</tr>
<tr>
<td>E B7</td>
<td>1.64</td>
<td>1.83</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>1.75</td>
<td>1.95</td>
<td>2.40</td>
</tr>
<tr>
<td>F B6</td>
<td>0.985</td>
<td>1.09</td>
<td>1.14</td>
</tr>
<tr>
<td>G B5</td>
<td>1.36</td>
<td>1.47</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>1.37</td>
<td>1.48</td>
<td>1.83</td>
</tr>
<tr>
<td>H</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>I B9</td>
<td>1.31</td>
<td>1.44</td>
<td>1.53</td>
</tr>
<tr>
<td>C6</td>
<td>1.18</td>
<td>1.30</td>
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<td>----</td>
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<tr>
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<td>1.56</td>
<td>1.68</td>
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<td>1.96</td>
<td>2.55</td>
</tr>
<tr>
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<td>1.74</td>
<td>1.94</td>
<td>2.72</td>
</tr>
<tr>
<td>N</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
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<td>Sample</td>
<td>( \text{NT as a percentage of:} )</td>
<td></td>
</tr>
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<td>--------</td>
<td>----------------------------------</td>
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<td><strong>Oven Dry Weight</strong></td>
</tr>
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<td>1.39</td>
<td>1.49</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>2.00</td>
<td>2.27</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>B1</td>
<td>1.41</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td>B2</td>
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<td>2.48</td>
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<td>A4</td>
<td>2.00</td>
<td>2.12</td>
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<tr>
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<td>2.57</td>
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<tr>
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<td>2.77</td>
</tr>
<tr>
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<td>B6</td>
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<td>2.38</td>
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<td>B5</td>
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<td>2.22</td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>2.23</td>
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<td>B12</td>
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<td></td>
<td>2.05</td>
<td>2.24</td>
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<tr>
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</tr>
<tr>
<td>L</td>
<td>B10</td>
<td>2.32</td>
<td>2.50</td>
</tr>
<tr>
<td>M</td>
<td>B11</td>
<td>2.63</td>
<td>2.93</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
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</table>
TABLE 10.
Amount of Ammonia Fixed (Nf) by Samples After Ammoniation.

Nf expressed as percentage of:

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample</th>
<th>Air Dry Weight</th>
<th>Oven Dry Weight</th>
<th>Ignition Loss</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>RANGE</td>
<td>AVERAGE</td>
<td>RANGE</td>
</tr>
<tr>
<td>A</td>
<td>A1</td>
<td>0.35 - 0.45</td>
<td>0.40</td>
<td>0.28 - 0.48</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>0.64</td>
<td>0.64</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.24 - 0.64</td>
<td>0.44</td>
<td>0.22 - 0.71</td>
</tr>
<tr>
<td>B</td>
<td>Max.</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>C</td>
<td>B2</td>
<td>1.4</td>
<td>1.4</td>
<td>0.44 - 0.45</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.71 - 1.4</td>
<td>1.1</td>
<td>0.44 - 0.96</td>
</tr>
<tr>
<td>D</td>
<td>A4</td>
<td>0.43 - 0.61</td>
<td>0.52</td>
<td>0.44 - 0.71</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>0.19 - 0.20</td>
<td>0.19</td>
<td>0.21 - 0.22</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.19 - 0.61</td>
<td>0.40</td>
<td>0.21 - 0.71</td>
</tr>
<tr>
<td>E</td>
<td>B7</td>
<td>0.50 - 0.61</td>
<td>0.56</td>
<td>0.56 - 0.68</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.44 - 0.68</td>
<td>0.56</td>
<td>0.46 - 0.74</td>
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<tr>
<td>F</td>
<td>B6</td>
<td>0.65</td>
<td>0.65</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.62 - 0.65</td>
<td>0.64</td>
<td>0.48 - 0.51</td>
</tr>
<tr>
<td>G</td>
<td>B5</td>
<td>0.36 - 0.44</td>
<td>0.40</td>
<td>0.39 - 0.47</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.36 - 0.44</td>
<td>0.40</td>
<td>0.39 - 0.47</td>
</tr>
<tr>
<td>H</td>
<td>Max.</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>I</td>
<td>B9</td>
<td>0.70</td>
<td>0.70</td>
<td>0.76</td>
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<td></td>
<td>C6</td>
<td>0.48</td>
<td>0.48</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.48 - 0.70</td>
<td>0.59</td>
<td>0.55 - 0.76</td>
</tr>
<tr>
<td>J</td>
<td>B12</td>
<td>0.27 - 0.422</td>
<td>0.34</td>
<td>0.30 - 0.45</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.06 - 0.42</td>
<td>0.24</td>
<td>0.02 - 0.45</td>
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<tr>
<td>K</td>
<td>Max.</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>L</td>
<td>B10</td>
<td>0.49 - 0.75</td>
<td>0.62</td>
<td>0.53 - 0.81</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.49 - 0.75</td>
<td>0.62</td>
<td>0.53 - 0.81</td>
</tr>
<tr>
<td>M</td>
<td>B11</td>
<td>0.40</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>0.40</td>
<td>0.40</td>
<td>0.44 - 0.45</td>
</tr>
<tr>
<td>N</td>
<td>Max.</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
</tbody>
</table>
EXPLANATION OF SYMBOLS ON THE FOLLOWING GRAPHS

To facilitate comparisons of samples taken from different locations the following symbols have been used:

○ indicates the value of a sample taken from the top of a hummock.

● indicates the value of a sample taken from the top of a hummock which was eroded.

• indicates the value of a sample taken from a hollow.

○—○ indicates a range of values which resulted from more than one analysis, of the type indicated, of any particular sample.
GRAPH 1.

Ash Content in Relation to Initial Kjeldahl Nitrogen Content (N° Kjeldahl) of Peat Samples.

Ash Content in grams per 100 grams of Oven Dry Peat.

N° Kjeldahl as a Percentage of Oven Dry Weight of Peat.
GRAPH 2.

Initial Kjeldahl Nitrogen (N₀ Kjeldahl) in Relation to Kjeldahl Nitrogen (Nᴬ Kjeldahl) Ammoniated Peat Samples, Both as a Percentage of Oven Dry Weight of the Sample.
GRAPH 3.

Ash Content in Relation to Kjeldahl Nitrogen Content

(N Kjeldahl) Ammoniated Peat Samples.

Ash Content in grams per 100g. Oven Dry Peat

N Kjeldahl as a Percentage of Oven Dry Weight.
GRAPH 4.
Total Nitrogen Content \(N^T\) of Ammoniated Peat Samples in Relation to Ash Alkalinity.

Ash Alkalinity in milliequivalents per 100g. Oven Dry Peat.
ADDENDUM

The author wishes to point out that the term "hummock" used in this work is synomic with the term "mound" used by Dr. N. W. Radforth in his work. Both terms occur in the literature.