AN INTRODUCTION TO THE STUDY OF THE STRUCTURE OF MUSKEG

AN INTRODUCTION TO THE STUDY OF THE STRUCTURE OF MUSKEG BY USE OF THIN SECTIONS

BY

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SCOPE AND CONTENT:

Qualitative and quantitative examination of undisturbed peat has escaped palaeobotanical attention with the result that no adequate means of reference to muskeg structure or synthesis has been available. This lack suggests the objectives of this investigation. A technique of analysis of peat samples utilizing macrofossils in the main is offered and the degree to which the botanical units are identifiable is suggested. An attempt is made to apply the results to the problem of explaining structural arrangements in peat.

PREFACE

Botanists and climatologists have utilized muskeg to reveal forest and climatic history. In the course of this, little has come to light concerning the structural relationship of the peaty material muskeg contains. It is thus unfortunate that knowledge is lacking concerning the elementary composition of a significant proportion of Canadian terrain. That this situation has become a matter for palaeobotanical investigation is not surprising because the character of peaty terrain is a function of, and perhaps controlled by the accumulation of plant remains.

I would like to express my gratitude to Dr. N.W. Radforth for his thoughtful suggestions and direction.

Also, I am indebted to McMaster University for awarding me a research scholarship in the Department of Biology. This made it possible for me to take part in muskeg investigation.

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INTRODUCTION

The study of peat is not new in the plant sciences, but in Canada is only ten years old and applies mainly to the north. The workers who have critically analysed organic terrain are numerous, but their objectives and those of the writer are different. From pollen histograms, palynologists have elucidated forest history. Climatologists have used their results to determine climatic changes. These changes in vegetation and climate are recent in the geologic sense of time, and they are determined for a time less than one million years ago.

In Canada, the study of muskeg has not been directed entirely to forest history and climatic changes. Radforth and his associates (12, 18, 19, 20, 21, 22, 24), after interpreting organization on a natural basis by relating terrain changes to microfossil frequency sequences in depth, then began investigations to show how macrostructure related to natural organization. He succeeded in showing how macrostructure varies consistently with microfossil history. However, macrostructure was expressed in qualitative terms, relative predominance of fibrosity vs. amorphous, and woodiness vs. non-woodiness. While this places macrointerpretation on a botanical basis, it suggests little about the genesis of muskeg in terms of systematics, and affords little toward quantitative measurement of the proportions of the macroingredients. These unsatisfied requirements have suggested the objectives of the work of this thesis. Delimitation of the problem has coincided with what appears to be three fundamental questions.

1. Can a method be devised to facilitate quantitative evaluation?

2. To what extent are macrostructures identifiable in terms of a natural system of classification?

3. Can 1. and 2. be co-ordinated and correlated with the mechanical system of reference used by Radforth (21) to designate peaty macrostructures?

If these steps can be achieved, the hypothesis that peat constitution and change can be assessed in palaeoecological terms will have received its initial test. The present method of assessing, artificial and therefore undesirably limited, will take on new and wider significance.

LITERATURE LIMITATIONS ON PEAT INTERPRETATION

In Scandinavia, von Post (23), one of the earliest workers in pollen analysis, determined forest succession and climatic history from the examination of micro and macrofossils in peats. His later work, along with that of Faegri (4) and Erdtman (3), has been used to interpret plant regeneration and forest succession in areas once glaciated. The methods established by the Scandinavians in pollen analysis are followed by the rest of the world.

Godwin and his associates (1, 5, 6, 7) in England have investigated the peat bogs of Somerset to interpret climatic history when early man lived in that area, and to date the associated archaeological findings. Also in Great Britain, Harley and Yemm (10) have studied the ecological aspects of peaty areas in Yorkshire.

In Ireland, Moore (15) has begun an investigation of the development of Irish bogs, and has attempted to classify them by surface vegetation. Two other Irish workers, Hanrahan (8) and Mitchell (14) have investigated the usefulness of peat types in steam generators and also in bearing capacity.

Hansen (9), in the Pacific North-West, has applied pollen analysis to bogs, and from the resulting pollen histograms has estimated the forest history since late-glacial times. In the U.S.A., Dachnowski-Stokes (2) has classified peats macroscopically, but his system is not universally adaptable in that it does not account completely for the degree of variability found in muskeg conditions generally; Radforth (21).

Moss (16, 17), and Lewis and Dowding (13), in Alberta, studied the ecology of muskeg areas, particularly changes in communities on the muskeg. Radforth (18, 19) and Johnson (12), emphasized the importance of microfossils (pollens and spores) originating from plants grown in situ as muskeg was developing. This was a new departure, and it lead to an understanding of patterns of organization in the vast areas of muskeg in northern Manitoba. Subsequently, Webb (24) and Radforth (18, 19, 20) derived a method of field reference for classifying muskeg coverage and related this to microfossil history. In 1955, Radforth (21) suggested a qualitative method by which the muskeg may be evaluated in terms of peat structure (Plate I, fig. 2).

This, and the work of Dachnowski-Stokes (2) are thus the only accounts which bear on the objectives of this thesis. Before further consideration can be made on macroscopic organization, a method must be devised to facilitate adequate structural interpretation.

MATERIAL AND METHODS

Appropriate selection of the material to be studied was made from a wide variety of samples collected chiefly from within a hundred mile radius of Fort Churchill by Dr. Radforth and his research assistants. From these, two contrasting samples were chosen for several reasons. First, the field notes on environment (drainage, surface vegetation, depth of permafrost, mineral sub-layer, and elevation above water level) were complete. Second, the surface vegetation of the areas from which the bores were taken were quite different; one was from beneath woody coverage, the other from non-woody. Third, the visual description of the peaty layer suggested structural contrast, and thus is desirable if the method of analysis evolved is to prescribe for wide range of peat construction.

Specific areas in the vicinity of Fort Churchill were chosen for detailed study. This meant that detailed knowledge from known areas would be obtained rather than unrelated facts from areas widely separated geographically. These specific areas were called the P areas.

One of the P areas was located four miles south of the military camp at Fort Churchill. It was designated the P_2 area (Plate II, fig. 3). Though the P_2 area was classed as woody, it was not totally covered by trees. Sedge meadows contained ponds of various size and the woody areas were on slight elevations known as lichen-heath plateaus. This area has been mapped to show surface vegetation, lakes and ponds (Plate II, fig. 4). The area was two and one quarter square miles. It was very flat with maximum elevation of ten feet. Both muskeg samples chosen for study came from this P_2 area and were labeled bore 475 and bore 476.

The classification system of surface vegetation proposed by Webb (24) and Radforth (18) was used in the P_2 area. The letters refer to life-form (Plate I, fig. 1).

The utilization of this system gave the formula BHE for the surface vegetation at the place where bore 475 was removed. BHE means that fifty per cent of the vegetation was woody material, five to fifteen feet in height (trees); twenty five per cent was non-woody (lichens); and twenty five per cent woody, up to two feet in height (ericaceous shrubs). The trees were identified as Picea glauca and Larix laracina, and the predominant ericaceous shrub was Ledum groenlandicum. The lichens were members of the genus Cladonia. The BHE area was a lichen-heath plateau which was about ten feet above the water level. The lichen-heath plateaus, though elevated, were not completely flat but were moundy with troughs which insured good drainage. When the peaty layer of the muskeg was removed, the mineral sub-layer revealed limestone plates mixed among grey-brown clay, gravel and limestone cobbles. The frost layer was reached at a depth of fifteen inches below the surface of the plateau. Bore 475 was categorized to peat type 13 by the use of Radforth's (21) chart.

The surface vegetation around bore 476 was classed as FI which means fifty per cent grasses and sedges and fifty per cent mosses. A pond was nearby so that when the bore was removed, the hole quickly filled with water up to two inches below the surface of the sedge meadow. But before the hole filled in with water, the mineral sub-layer was examined. It was composed of limestone plates, gravel and sticky grey clay. The frost depth was twenty-two inches below the surface of the meadow. By using Radforth's (21) chart, the peat structure was category 3.

If the structure and the macrofossils in muskeg are to be examined for quantitative evaluation, it will be appreciated that it is desirable that the macrofossils be studied in situ. This requires that an embedding medium be used to preserve the distribution and density relationships of the components of the portions of the major samples to be investigated. The nature of the peat is such that if thin sections are taken without the aid of a supporting medium, the peat will crumble.

Several methods of embedding the peaty layer of the muskeg were considered. The first was to embed the material in cellulose nitrate and to prepare the product for examination by transmitted light. To attempt this, peat was saturated in amyl acetate. Then it was placed in a concentrated solution of cellulose nitrate dissolved in amyl acetate. The amyl acetate was allowed to evaporate from the peat in a fume hood leaving it embedded in cellulose nitrate.

A second method was based on the possibility of embedding in gelatin.

The third method tried was paraffin infiltration. A sample one inch square was removed the length of the bore. It was divided at regular intervals. Test samples of two sizes were used; each were one square inch in cross-section; and some were one inch in depth; others were two inches, to get some idea concerning infiltration response.

The peat samples were placed directly into normal butyl alcohol for a week. During this time the samples were placed under vacuum to remove any air which may not have been displaced by the normal butyl alcohol. After seven days, all air bubbles had disappeared, even under vacuum. Each sample was transferred to an aluminium beaker containing melted paraffin. An experiment was tried by introducing the samples into a solution of equal volume of normal butyl alcohol and paraffin oil between the alcohol and the pure paraffin. The beakers containing the paraffin and the samples were kept in an oven at 62°C. for a week. During this time, the samples were placed under vacuum to remove the normal butyl alcohol which boiled off when pressure was decreased slightly. All traces of the alcohol were absent in seven days and the cubes were ready to be embedded. Johansen (11) recommended quick cooling of melted paraffin to avoid granules in it. The beakers were cooled in the deep freeze, but later most beakers were cooled in ice water. The paraffin containing the peaty material was removed from the beakers by standing them in warm water for a short time, then dumping out the paraffin. The excess paraffin was cut away leaving the cubes ready for sectioning.

The muskeg cubes were sectioned on a sliding microtome to a thickness of twenty microns. Johansen's (11) method of mounting the sections to the glass slides was followed. The standard method of dipping the slides in xylol to remove the paraffin was tried, but was discarded. A new method of removing the xylol was devised. Two glass rods were laid in the bottom of a petri plate. Xylol was added to just cover the rods. Then the glass slide was placed on the rods. Xylol was carefully pipetted from a reserve vessel into the petri plate until the slide was covered. After ten minutes, the xylol was carefully removed by a pipette. The peaty material on the slide was mounted in Canada Balsam.

RESULTS

(1) Techniques:

Infiltration with cellulose nitrate solution was rapid, effective and appropriate to the need for making large numbers of preparations in the shortest possible time. Unfortunately however, in the course of drying, shrinkage, distortion and displacement of the peaty elements took place. Cellulose nitrate was therefore discarded as a satisfactory embedding agent.

A similar set of circumstances was experienced with gelatin. Moreover, infiltration was slower and less certain. It too was discarded and attention was turned to the more attractive results obtained with paraffin.

Infiltration with paraffin was rapid, effective and conducive to quick preparation of mounts. The hardening process was apparently not accompanied by distortion of the peaty elements.

Observations suggested that the success of the embedding process was not entirely due to the paraffin. The normal butyl alcohol used as a precursor to infiltration was in part responsible for success. It softened the peaty material as a cube, and the removal of air allowed the tissues to be penetrated. Because paraffin and normal butyl alcohol are miscible, therefore, when the alcohol is removed by the heat of the oven and by the vacuum, all tissues which were penetrated by the alcohol will be penetrated by the paraffin. When normal butyl alcohol was utilized, the peaty elements, when ultimately embedded, were held firmly and infiltration was complete with paraffin penetrating all tissues and no lacunae visible.

The removal of the embedded sample of peat from the aluminium beakers provided a sample in which there was no distortion and for which mechanical injury was highly improbable. Therefore, the use of aluminium beakers which due to high heat conductivity properties facilitated the removal of the embedded mass. This is a very practical and desirable aid.

The technique of pipetting the xylol into the petri dish allowed the paraffin to be removed from the peaty constituents on the slide without disarranging them. This meant that the material on the slide was located in position relative to the position in situ.

The larger cubes took twice as long to process as did the smaller ones. As time was valuable, the smaller cubes were used.

(2) Analysis:

Examination of the mounts could be done with ease on a qualitative basis. Where tissue was preserved, outlines were clear and spacial relationship of the elements as they appeared in the field were such that visual differentiation could be appreciated without difficulty.

The material observed on the slides that were examined in a preliminary was appeared to suggest that construction properties of samples varied with respect to differences in density depending upon the frequency and distance apart of the different elements. To reveal density differences in measured terms (Table I and Table II, pp. 13,14 and 15, columns one and two), a Whipple disc was placed in the eyepiece of a microscope. The image of the disc was then superimposed on the mount as this was viewed under the microscope. In the case of five different areas randomly selected from the mount, the percentage of area covered by peaty elements was observed. This was achieved by counting the Whipple disc squares, the outlines of which appeared to confine peaty debris. Thus, if twenty five of the total one hundred squares on the disc covered peaty material and the remaining did not, density was defined as twenty five per cent for that field. Density computations for the five fields so examined were then averaged and the result designated as the density index for the level of the sample which the section represented. This procedure was performed for successive depths of one inch; for the cross-section at each depth and the longitudinal section of the sample. The density indices for successive depths are thus indicated in column one and two, Table I (Bore 475) and in column one and two, Table II (Bore 476).

Where counts were made, the peaty material was considered in terms of woody axes, bark and cuticle, leaves, and amorphous organic micronodules. Where lichenoous material appeared, its occurence was noted. It was convenient when recording density to note the percentage coverage per slide for each of the botanical categories to which reference has been made. Figures explaining frequency are shown in Tables I and II. This system of recording was useful whether referring to material of woody or non-woody origin.

TABLE I (Bore 475)

Depth in Inches	Density in Per cent	Woody in %			In %	In %
		Axes	Loose Bark and Cuticle	Leaves	Lichen	Amorphorous Granular
0-1 c.s.	18	1	5	-	12	-
0-1 l.s.	43	12	13	-	18	-
1-2 c.s.	34	21	6	7	-	7
1-2 l.s.	40	17	9	14	-	17
2-3 c.s.	43	36	7	-	-	17
2-3 l.s.	41	29	12	-	-	29
3-4 c.s.	41	35	6	-	-	16
3-4 l.s.	48	34	14	-	-	50
4-5 c.s.	45	30	15	-	-	42
4-5 l.s.	53	33	20	-	-	63
5-6 c.s.	60	45	15	-	-	60
5-6 l.s.	77	63	14	-	-	70

TABLE II (Bore 476)

Depth in inches	Density in %	Non-Woody Stems & Leaves in %	Amorphous Granular in %
0-1 c.s.	27	27	0
0-1 l.s.	25	25	0
1-2 c.s.	30	30	8
1-2 l.s.	62	62	20
2-3 c.s.	69	69	35
2-3 l.s.	38	38	30
3-4 c.s.	78	78	30
3-4 l.s.	69	69	30
4-5 c.s.	81	81	30
4-5 l.s.	69	69	30
5-6 c.s.	70	70	40
5-6 l.s.	69	69	40
6-7 c.s.	73	73	45
6-7 l.s.	75	75	50

TABLE II (Bore 476) - Cont.

Depth in inches	Density in %	Non-Woody Stems & Leaves in %	Amorphous Granular in %
7-8 c.s.	86	86	50
7-8 l.s.	89	89	80
8-9 c.s.	93	93	85
8-9 l.s.	95	95	90

(3) Systematics of peaty derivatives:

Reference to botanical origin of the peaty elements is essential if a consideration of the natural relationships expressed by the peat is to be attempted. For the purposes of the objectives of this thesis, this requirement is predominantly satisfied when the botanical arrangement is in organographic terms. It would be unfortunate, however, if at this time some assessment was not made of the possibility of interpreting the genesis of peat particles in terms of the systematic approach since it will be appreciated that natural affinity is best understood in terms of organisms rather than unnamed organs.

Some difficulty in achieving this was experienced as a result of different preservation of all parts of organs necessary for assignment to a taxon. In many instances where preservation was satisfactory, insufficient was known concerning the morphological and anatomical details of the species to which the fragments might be assigned. Finally, it is well known that parts of given organs vary considerably as to structural detail, and these variations must be studied *in toto* before assignment to the appropriate taxon can be made. Anticipating the possibility of classification in future work, an opportunity was exploited here of ascertaining the relative degree to which various kinds of tissue detail could be observed.

In bore 475, only a small amount of leafy material was identifiable. The cross-section of a leaf on Pl. XI, fig. 41, has been identified as the needle of a *Picea* sp. The characteristic rhomboidal shape, and the dense vascular bundle embedded in cortical cells with characteristic invagination helped identification. Spores and pollen grains were occasionally found, and some are illustrated on Pl. XI, fig. 37,38,40,42. When they were found, they were generally separate, but groups of them were also found (Pl. XI, fig. 37,38,40). Cuticular particles were small and dense (Pl. XI, fig. 43). A few cross-sections of roots were seen in the sections. Pl. XI, fig. 39 shows a typical mature root cross-section with a well defined corky layer and endodermis enclosing the stele. The smallness of the root and the thickness of the section meant that a detailed photograph of the stele was of little use. Tracheids and bordered pits were seen (Pl. XII, fig. 44, Pl. XI, fig. 35). The bordered pits were located on a slide of peaty material which was four inches below the surface of the muskeg, or two thirds of the depth of bore 475. Cross-sections of woody stems were frequently observed and two examples are shown (Pl. XI, fig. 36, Pl. XII, fig. 48). The peaty material found on the slides which came from the two cubes closest to the mineral sub-layer had a colour change within the cells. They were darker in colour, and apparently were in the process of being filled with an amber coloured material (Pl. XII, fig. 46).

In bore 476, the nature of the organ fragments and plant cells was much different from those in bore 475. The non-woody stems of bore 476 (Pl. XII, fig. 47, Pl. XIV, fig. 64,66,67) contrast to the woody stems of bore 475 (Pl. XII, fig. 44) in characteristic shape of cells, and colour of cell walls. The long, thin walled nature of the non-woody cells are easily distinguishable from the shorter cells with thicker cell walls of the woody fragments. Though the photographs do not indicate colour exactly, the non-woody material had a characteristic yellow colour, and the woody material was white-yellow and/or brown-yellow. Only a slight colour change was observed within the samples from one bore, except for the darkening in colour of the cells in the bottom cubes.

Bore 476 was investigated in similar fashion to that used for bore 475 appraisal with respect to stems, leaves, and amorphous organic micronodules. Cross-sections of non-woody stems (Pl. XIV, fig. 63,68) from bore 476, can be contrasted to woody stem cross-sections (Pl. XII, fig. 46) from bore 475 with respect to woodiness. Other non-woody stem material is shown on Pl. XIII, fig. 57,60,61. In Pl. XIII, fig. 57, a small stele is apparently surrounded by a large cortex. This can be contrasted to Pl. XIII, fig. 60,61, where the cortical cells around the stele suggest an aerenchymous condition with vertical plates of tissue. Pl. XIII, fig. 58, is possibly a longitudinal section of stems similar to those shown on Pl. XIII, fig. 60,61. Longitudinal sections of the non-woody stems in bore 475 show the branching of the leaves from the stem (Pl. XIII, fig. 59; Pl. XIV, fig. 66,67). A close examination of Pl. XIV, fig. 67, showed scalariform tracheids. It is to be appreciated that shape of sections is in part a function of the plane of section, and this must be taken into consideration for identification purposes. The leaf material displaced many shapes as a result of this factor (Pl. XII, fig. 48,52; Pl. XIII, fig. 4/,5/2,53,54,56; Pl. XIV, fig. 62, 63,65). Though the leafy material had these varied shapes identification was easy because of the characteristic thin walled cells of a light yellow colour. The most abundant material in regards to numbers on the slides was classed as amorphous granular. These organic micronodules ranged in size from one to twenty five microns in size, and were unidentifiable because they lacked cellular detail (Pl. XIV, fig. 70). Two spherical bodies were identified as perithecia of the Phyllactinia sp. (Pl. XII, fig. 49; Pl. XIV, fig. 69), because of the characteristic bulbous shape of the appendages whose walls vary in thickness. Though Pl. XIV, fig. 69, lacks the appendages, the size and shape is similar to Pl. XII, fig. 49, and the darkness around the edges shows that it is a spherical object. The mount also contained material which can not be identified at present, though tentatively it has been. Pl. XIII, fig. 55, has been classed as leafy material because its cell colour is similar to that of non-woody leaves. Pl. XII, fig. 50, 51, has been classed as axial because in fig. 50, the stele resembles the stele of a water plant being surrounded by aerenchymous cortical cells, and fig. 51, apparently has vascular material arranged in the dense outer ring.

(4) Evidence pertaining to peat synthesis:

When the slides were examined with the aid of a dissecting and compound microscope, it was apparent that the peaty fragments were not simply mechanically arranged, but they were oriented according to design which seemed appropriate to the botanical origin of the components. The macrofossils were organized into major and minor elements which controlled and affected the nature of the peat. The botanical elements which were of major importance were the fibrous axes, both woody and non-woody, and the minor elements in the peat were the leaves, cuticle, bark, and licheneous material when found.

In general, the cross-sections of the peat samples showed an abundance of longitudinal cuts of the stems, while the longitudinal sections showed a large number of cross-sections of axes. Pl. V, fig. 13, as contrasted to Pl. V, fig. 14, shows this as marked. The cross-sections of material was generally at right angles to the length of the material, but often the longitudinal sections cut the material at an oblique angle (Pl. VIII, fig. 25). The fibrous axes which show up well in Pl. III, fig. 7,8, are less dense at deeper levels. They are, however, probably more abundant, but are obscured by the crowding effect of the surrounding debris.

The main supporting structures, "the skeleton" of the peat, are the fibrous axes. Every figure from fig. 5 to fig. 34 show them, whether woody or non-woody. Around this relatively hard framework, the other non-resistant particles of organic debris are packed. In bore 476, particles similar to the leafy material shown as Pl. XIII, fig. 56, were found filling the interstices. In bore 475, the woody material evidently did not fracture so easily. Fragmentation did occur with depth, but not as markedly as for bore 476. This observation would in part explain the lower density index referred to in Table I, column 2, 5" to 6", confirming determinations which were arrived at independently.

Appraisal of the section made it easy to assess on a qualitative basis relative compaction for different levels in the peat samples.

In both bore 475 and bore 476, the top inch showed very little compaction, therefore, the photographs do not show much organic material (Pl. III, fig. 5,6; Pl. VIII, fig. 23,24). The increase in density with depth is clear in Pl. VIII, fig. 24, from the top to the bottom of the figure. Two more examples of density increase with an inch are Pl. VI, fig. 20, and Pl. IV, fig. 12. The figures on all plates from III to VII inclusive are from bore 476 and show the increase in density with depth in non-woody material. Plates VIII to X inclusive show density increase in bore 475 of woody material.

The particles of cuticle and bark in bore 475 are not packed around the woody stems as are the non-woody leaves around non-woody stems. Instead, the cuticle and bark appear to be relatively stable as they do not increase in abundance with depth. This almost constant abundance of cuticle and bark relegates them to a minor importance in peat synthesis, but they are not as insignificant as are amorphous granular particles.

Though the matrix in bore 475 did not have the interstices so densely filled as did that for bore 476, each bore possessed a high percentage of amorphous granular particles. These were found throughout the samples but increased in per cent with depth. Other than the increase in percentage with depth, amorphous granular particles were not apparently a factor in peat synthesis.

The occurrence of pollen grains, spores and perithecia were not apparently related to the general structure of the peaty material.

Often in bore 476, the arrangement of the leafy material appeared as to suggest the presence of a hollow stem, but cellular detail as seen with the aid of a microscope showed that the tissue was leafy and lacked the supporting and conductive structure of axes. The upper left hand corner of Pl. IV, fig. 11, shows a cross-section through a group of leaves which illustrate this point. In the centre of Pl. IV, fig. 10, the long stem-like axis actually is leafy as conductive tissue was not present.

The licheneous material in bore 475 was the major component of the structure of the peat in the top layer. This material was not compacted, and though it was of prime importance in the upper inch of bore 475, it was lacking elsewhere.

DISCUSSION

Because of the emphasis on analytical procedure in this comparatively new field, technical refinement has been given more than usual attention. The desirability of preparing the peat for examination in such fashion as to preserve the in situ spacial relationship characteristics prove to be the major technical difficulty. Mechanical disturbance of the peaty ingredients could easily arise either as a result of the embedding process or differential segregation of units in the pre-infiltration stage.

The shrinkage imposed on the peat matix due to drying of the cellulose nitrate medium made the latter undesirable. The contraction of the cellulose nitrate as the amyl acetate evaporated was consistent and could not be obviated. Possibly this condition could be substantially altered if infiltration procedure was extended in time and in terms of successively stronger dilutions of cellulose nitrate. However, this would lengthon total procedure and make the technique impractical.

In contrast to the cellulose nitrate, the gelatin showed poor penetration properties and procedure was retarded. Besides this, the gelatin also shrank as it dried. The in situ arrangement of the peat was thus destroyed.

The difficulties experienced in the application of the first two potential embedding media were solved with the application of the third, paraffin.

Because the samples were dry, it was not necessary to dehydrate the material through the use of alcohol solutions. But if fresh, moist material were to be used, an additional step would have to be added to the technique to insure the removal of water from the peat, resulting in lengthening procedure undesirably.

The larger size of samples tried was not used because it required twice as long to embed with no advantage contributed for analytic result. The smaller, one inch cubes were satisfactory because the embedding process was shorter and adequate for analytical requirement. It was learned that peat material changes rapidly with every successive inch (pp. 13,14,15), therefore, the use of samples at inch intervals was far superior to samples at intervals of two inches in depth. The square inch of material on the slide gave the desired results as within a square inch, enough of the arrangements are seen to reconstruct the structural circumstances on a local basis for the corresponding levels.

Because normal butyl alcohol was known to be miscible with liquid paraffin, it was used as a pre-infiltration medium. Not only this feature of it was favourable, but also normal butyl alcohol softened the peat somewhat facilitating paraffin infiltration and discouraging breakage of fine peaty elements. It also penetrated the tissues apparently completely. The low boiling point of this liquid meant that most of it would evaporate in a warm oven notwithstanding the large volume trapped within the peat which took longer to remove in equivalent time. This also favoured the need for keeping distortion to a minimum.

The distortion of the material due to the effect of the vacuum pump, used for removing the last traces of normal butyl alcohol as this was undergoing replacement by paraffin,was apparently negligible because no visible change, such as fragmentation, occurred in them. Though the use of normal butyl alcohol reduced the number of times the vacuum pump had to be used, it was only by lowering the pressure on the last day of the procedure till the medium started to evaporate could it be certain that all traces of air or normal butyl alcohol were removed.

Because no apparent changes occurred in the samples saturated in normal butyl alcohol when they were placed directly into paraffin, the intermediate step of fifty per cent normal butyl alcohol and fifty per cent paraffin oil was discarded. It had increased the procedure by one day.

If any shrinkage or distortion occurred while the paraffin cooled, it was not apparent.

The time intervals of a week in both normal butyl alcohol and paraffin may be excessively long, but they insured certainty of penetration, and in any case were shorter than those periods which would have been required if the wetting of the peaty elements by a paraffin solvent had been achieved by application of dilution rather than vacuum.

The cracking of the paraffin which took place when it was cooled quickly in the deep freeze implied that cooling was too rapid. Johansen (11) recommended quick cooling, but he definitly referred to ice water which was used for all the successful embeddings. It is thus important to select a cooling temperature somewhat above 0°C. and to use water rather than air to encourage the rapid dissipation of heat from the paraffin.

Glass beakers would not be effective in this technique because the removal of the solid paraffin containing the muskeg from them would mean melting most of the paraffin with the possibility of disturbing the material. On the other hand, aluminium beakers were effective because of aluminium's high heat conductivity, the paraffin containing the samples was removed without melting the majority of the paraffin.

Though the sections taken at 20 μ give satisfactory results, they are too thick for microphotographs at high power which would be of use in identification problems if the material was being reduced to a taxon. It is, therefore, suggested that sections be made at 12 μ but if they are, the embedding material will be extremely thin to hold together all the particles both woody and non-woody in one square inch.

The orthodox method of removing the paraffin from the sections was not effective in this problem. When the slides were dipped into a xylol bath, the force of the surface tension was greater than the force of the adhesive holding the material to the slide. To overcome this difficulty, a method was devised whereby xylol was added and removed from a stationary slide. When the mount was applied to the fluid, the arrangement of the particles was completely disrupted, but when the reverse procedure was applied, the particles retained their organic orientation.

The use of quantitative figures on the relative amounts of organic substances found in muskeg samples is considered for the first time in this work as far as this writer is aware. Up till now, the work on macrofossils in peat, as they relate to fibrosity and therefore structure, has been qualitative.

The use of a Whipple disc in the eyepiece of a microscope made examination of selected areas on the slides feasible. It could be ascertained that increase in density was accompanied by increase in density of association of elements. Though it was obvious from qualitative observations that density increased, it is now possible to measure the density increase. Now that density can be determined on a quantitative measured basis, the peat can be appreciated as identified by its density index. It seems appropriate to point out that the use of the Whipple disc was of great value in the achieving of quantitative results because the image of the Whipple disc provided the squares which appeared either to contain or not to contain peaty elements. This information considered with the identification attended the botanical classification of the elements gives the most reasonable reference entity that can be devised.

That the percentage of woody axes increases with depth, is possible due to compaction and also to the resistance of its cells to disintegration and fracture under pressure. This would explain why bore 475 has a lower density index in its deepest sample, than does bore 476 at its deepest sample.

The relative abundance of axial material, and amorphous organic nodules increased in depth, but the bark and cuticular particles did not. It stayed fairly constant, therefore as it was compacted, it must have been broken up still further to form amorphous granules. It seems unlikely that a material would have a constant proportion with depth as compaction occurred unless fragmentation was proportional to the rate of compaction.

Because the leaves were often attached to the stems in bore 476, they were counted together and gave the same index number as the density index. With all the material being of a non-woody type, and being either leaves or stems, it seems that peaty material of this type would be the simplest to identify to family or even to genus.

The apparent absence of leafy material in bore 475 is of significance because a trace of it has been found, yet it is not abundant. The leaves of ericaceous shrubs are leathery, and pine needles have a thick cuticle, so preservation of them is to be expected. From their almost complete absence, it appears that they fragmentize easily in the course of fossilization.

From Table I, column 5, it is seen that the lichen index has been recorded for only the top inch of the bore. These numbers do not signify absence of licheneous material because it may occur but be obscured by the compaction of the woody axes. Lichens also may be new to the ecological community, or they may decay easily. In any case, no traces of it are found below a depth of one inch so the bore can be called woody rather than woody and non-woody as is the surface vegetation.

The increase in amorphous granular particles, though apparently of great importance from the index numbers on Table I and Table II, does not affect the structure of the peat to a considerable extent because the total effect of such small particles is almost colloidal. If they have colloidal effect, they may affect the amount of water held in bore 475 which came from a well drained area.

The amount of material in bore 475 which could be identified as leafy was slight, due it is believed to fragmentation. But a spruce needle was identified which suggested the occurrence of a spruce tree very close to the place where the needle was found as spruce needles with their density do not blow far from the parent tree when they fall. Without the knowledge concerning the evidence of the spruce needle, it might have been construed that this sample of peat did not support shrub or tree growth at any stage in its existence. It will be appreciated that the identification, if based on one type of organ, will not necessarily lead to the valid conception of the structure of the peat. The non-woody leafy material in bore 476 appeared to be similar in cellular design throughout the bore. Though further identification, it is suggested by the material itself that non-woody leafy material has always been a function of the structure of the peat.

Some emphasis should be placed on the results concerning the pollen. Palynologists have used methods which effectively isolate pollen constituents which are representatives at corresponding levels in the peat. On occasion, it has been found that unexpectedly high counts of given examples appeared in the data. The fact that micro-fossils may occur in groups as this work has demonstrated would suggest a good reason this type of anomalies that palynologists may find.

It is perhaps unfortunate that cuticle and bark is not readily identifiable on a genus-species basis. However, its presence encourages a view that the origin of the peat has been from woody sources. This view is strengthened by the association of large amounts of woody material along with the bark and cuticle. A comparison of bore 475 to bore 476 in regard to presence or absence of cuticle and bark enhances this situation.

The fact that cross-sections of roots were seldom found is not without significance. Non-woody fibrosity can perhaps be now explained as a result of the high incidence of linear leaves such as those of the sedges. Therefore, this kind of peaty matrix is predominantly derived from aerial parts of plants rather than from underground organs. It may also prompt the interpreter to carefully weigh the possibility of occurrence of sphagnum. Thus, lack of roots in the microscopic evidence indirectly points to positive identification in relation to either sphagnum or sedge.

The presence of scalariform tracheids indicates either presence of metaxylem of Gymnosperms, or xylem of more primative herbaceous Pteropsides, and the accompaniment of border pits suggests the occurrence of secondary xylem of Gymnosperms. These have little inherent significance because occurrence is often casual. Like the cuticle and bark examples, these can however be used in an indirect way as collateral evidence. When they occur, the genesis of the peat must surely be regarded with reference to conifers.

The colour change in the cellular material which was observed near the mineral sub-layer may be due to the compression of the matrix by the force of the water as it freezes between the frozen surface layer and the permafrost. The mineral sub-layer may also affect organic material and so cause this change. Probably the most plausible explanation of colour change would be with reference to inherent biochemical change of the fossil material and the natural accumulation of organic acids which increases with time. The mechanics by which this is attained is not completely understood and moreover is not the subject of this investigation. Also colour of peat material as seen in the sections is a dangerous criteria for identification if an attempt to make use of it in the absolute sense. However, a lead to the kind of peat can often be made with reference to colour as preliminary interpretation is applied. Positive identification of this darker material to taxon is unlikely because the colour change obscures cellular detail.

If the axial material were to be identified to genus, which is not the fundamental requirement of this work, the material under study would have to be examined in greater detail for morphological and anatomical attributes. This could not be done, because the material was too thick for the desired optical resolution. The amount of sectional axial material was not a limiting factor because many sections, both longitudinal and cross, were available for study. But even if the peaty material were studied for anatomical details, these results would have to be compared to the details of a known taxon which had previously been described. This reference source is lacking for material in this problem.

Due to the environmental circumstances in northern Manitoba, the effect of bacteria and fungal agents is expected to be slight because peat is still accumulating rather than decaying. Though microrganism are present as indicated by the perithecia of Phyllactinia sp., it is not the purpose of this paper to investigate the effect or abundance of microrganisms. The fact that fungal remains are discernible is of little significance in the direct sense in estimating natural structural relationship of the peat. However, analysis on occasion may show inadequate amounts of important structural elements with the desirable degree of clarity. In these cases, units of secondary importance such as Phyllactinia, may, if identifiable, be elevated in significance in that they refer unquestionably to the hosts with which they were associated.

Though amorphous granular particles are generally present in large number, it is unlikely that they will ever be identified because of their lack of cellular detail, and small size. On the other hand, there is a need for differentiating those kinds of organic terrain in which the amorphous granular components predominate. Recourse to chemical analysis may be desirable here, especially if the amorphous granular component so analysed can be ultimately related to botanical origin.

Most axes were exposed in cross-section by longitudinal cuts on the sample faces which indicates that the axes are generally preserved in a plane parallel to that of the surface. It is instructive to note that the organization developed by the accumulation of horizontal members is due to a combination of method of fossilization and botanical environment. The understanding of this affords a useful application for those who would interpret peat structure on the basis of mechanical proportions alone. Those axes apparently do not touch each other as they are deposited, but compaction forces them together so that they do, and if more pressure is applied, one of the crossed axes would probably fracture. It is from this fact that the increase in fragments is explained with depth.

If the woody and non-woody axes had disintergrated into amorphous granules, the peat would not have its characteristic structure. But because the axes have resisted fracture and have remained as fairly large macrofossils, they indicate the type of fibrosity of the peat. The woody axes have given a coarse fibrosity, and the non-woody have a fine fibrosity. But the peat types do not depend only on the axes.

Though the major emphasis in peat structure is upon the axial material, the abundance and type of bark and cuticle is important. These particles, believed to be a result of fracturing, by partially filling the interstices with woody material, which is relatively non compressible, give support in a small way to the woody axes. By resisting compaction along with the woody axes, the bark and cuticle help to make the density index fairly low, and in doing this, increase drainage in the woody bore.

The non-woody leafy material has almost an equal amount of supporting tissue in it as does the fine fibrous non-woody axes characteristic of bore 476. This means that they almost equally resist the compaction due to depth, but the absence of strengthening material in the large proportions found in bore 475 results in comparatively easy packing. If a bore could be reconstructed in the lab, it would be expected that if it was composed of woody axes and non-woody leafy material, it would compact more than an all woody bore, but less than an all non-woody bore.

Though the increase of amorphous granular particles in bore 475 appears to be a result of fragmentation of the bark and cuticle, leaving it a constant, they show no other effect in peat synthesis. Rather, amorphous granular particles appear to be a result of peat synthesis. Attempts to attain a clear picture of the botanical synthesis of peat, based on amorphous granular material, is difficult if not impossible because the difference between the two bores did not suggest a basis for discrimination.

The preservation of pollen grains is in part due to the condition peat provides. They and amorphous granular particles have almost no effect in peat synthesis because of the small amount of organic material in them.

The high proportion of licheneous material in the first inch of bore 475, and then its sudden disappearance did not lack in significance. By reasoning backwards from the surface vegetation, bore 475 would be expected to be composed of equal parts of woody and non-woody (licheneous) material. But this reasoning only holds true for the first inch, after which the peaty elements were all woody. It would, therefore, be reasoned that wherever HE are used as code letters to expect the major portion of the peat to be woody in nature. If the licheneous material had remained in the peat, the density index doubtless would have been higher because the non-woody lichens would have packed.

SUMMARY AND CONCLUSIONS

The modified technique of paraffin infiltration and embedding, developed and used in this work, has provided an adequate means for analysing and assessing details of peat construction on a quantitative and qualitative basis. Principally, it should be emphasized that infiltrating solutions may be dispensed with, fresh field samples of peat should be oven dried, and that paraffin replacement in the final stages of the process can be achieved by syringing with xylol while the mount is under visual observation.

That disturbance of the peaty elements has been avoided becomes significant when quantitative determinations are required from the examination of the mounts. Measurement of difference between examples of peat from different locations can be achieved by the application of the density index method prescribed in this work. It must not be construed, however, that the qualitative method evolved without fault. Refinements may be anticipated in counting procedure. It is hoped that where such refinement is possible, slight differences evident in some of the comparative results will take on new significance.

Macro-elements in both peat samples investigated were identified. Observation has suggested that identification can be considered in botanical terms, and on the basis of organ structure. A classification system based on utilization of taxa is not possible at this stage of macrofossil investigation. However, this does not prevent the appreciation of peaty structure in natural terms; woody axes, leaves, roots, microfossils and characteristic debris, all identifiable, can be incorporated into a natural system of reference, and given sections of peat samples can be accounted for in entirety.

The results of identification are such that they can be utilized to suggest the natural course of peat synthesis. Information towards this end, though encouraging, is not complete. The chief reason for this is that not all fossilized organ remnants, though identifiable, are not always referable to living taxa. Hence, peat synthesis for the time being at least will have to be considered on the basis of morphology as they relate to ecology.

Differentiation of peat samples on the basis of the system suggested has been demonstrated. The relationship between the composition considered and the constitution of surface vegetation can be established through the approach used in this work. For at least two kinds of muskeg coverage, (those selected in this investigation), clarification of sub-surface structure has been afforded. What is perhaps more significant is that the approach itself seems to be adaptable for the examination of this problem in general.

Field reference to structure of peat as suggested in the categorization by Radforth (21) has been substantially collaborated as being reasonable on botanical grounds. It must be emphasized that this claim can only be made with reference to two types of peat, but the method is now available for the examination of others.

The claim that peat structure can be appreciated in palaeoecological terms has in part been demonstrated. Wide application of the system developed will demonstrate the extent to which this claim may be regarded as valid.

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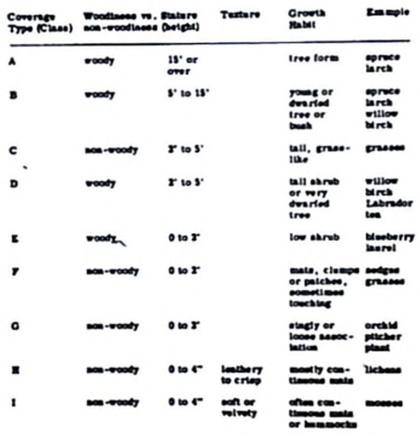
DESCRIPTION OF PLATES

PLATE I

Fig. 1. - A chart showing the classification of surface vegetation as proposed by Radforth (18).

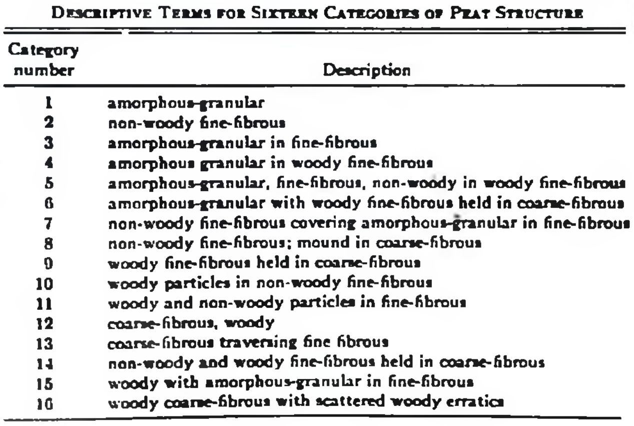
Fig. 2. - A chart showing the sixteen categories of peat types as proposed by Radforth (21).

PLATE I



Coverage Type (Class)	Woodiness vs. non-woodiness	Stature (height)	Texture	Growth Habit	Example
A	woody	15' or over		tree form	spruce larch
B	woody	5' to 15'		young or dwarfed tree or bush	spruce larch willow birch
C	non-woody	2' to 5'		tall, grass-like	grasses
D	woody	2' to 5'		tall shrub or very dwarfed tree	willow birch Labrador tea
E	woody	0 to 2'		low shrub	blueberry laurel
F	non-woody	0 to 2'		mats, clumps or patches, sometimes touching	sedges grasses
G	non-woody	0 to 2'		singly or loose association	orchid pitcher plant
H	non-woody	0 to 4"	leathery to crisp	mostly continuous mats	lichens
I	non-woody	0 to 4"	soft or velvety	often continuous mats or hammocks	mosses

FIG.1



Descriptive Terms for Sixteen Categories of Peat Structure

Category number	Description
1	amorphous-granular
2	non-woody fine-fibrous
3	amorphous-granular in fine-fibrous
4	amorphous granular in woody fine-fibrous
5	amorphous-granular, fine-fibrous, non-woody in woody fine-fibrous
6	amorphous-granular with woody fine-fibrous held in coarse-fibrous
7	non-woody fine-fibrous covering amorphous-granular in fine-fibrous
8	non-woody fine-fibrous; mound in coarse-fibrous
9	woody fine-fibrous held in coarse-fibrous
10	woody particles in non-woody fine-fibrous
11	woody and non-woody particles in fine-fibrous
12	coarse-fibrous, woody
13	coarse-fibrous traversing fine fibrous
14	non-woody and woody fine-fibrous held in coarse-fibrous
15	woody with amorphous-granular in fine-fibrous
16	woody coarse-fibrous with scattered woody erratics

FIG.2

PLATE II

Fig. 3. - A map showing the location of the P_2 area in relation to Fort Churchill Military Camp and the town of Churchill, Man.

Fig. 4. - An enlarged map of the P_2 area showing the ponds and lakes, and the vegetation as classified by the chart shown by Pl. I, fig. 1.

PLATE II

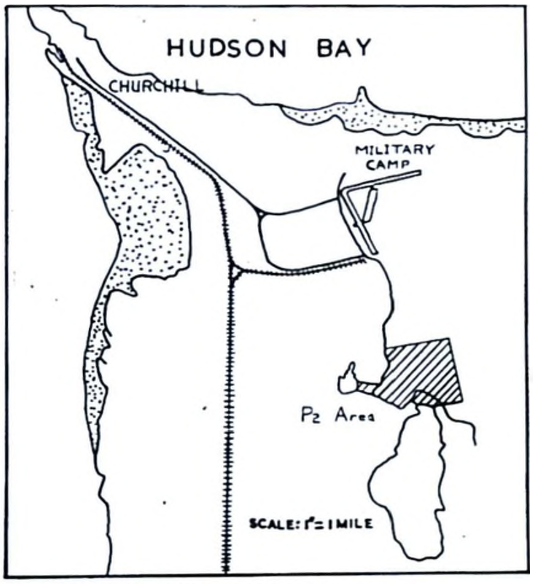


FIG. 3

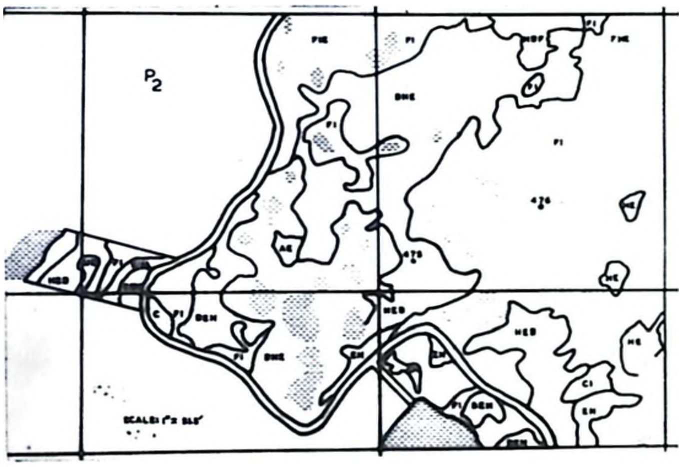


FIG. 4

PLATE III

Fig. 5. - Low density is shown by this cross-section. Mag. 3.5X. Taken at surface level of bore 476.

Fig. 6. - The organic elements are not compacted. Mag. 3.5X. A Longitudinal section between 0-1" in bore 476.

Fig. 7. - Note the longitudinal section of non-woody axes. Mag. 3.5X. A cross-section of bore 476 at depth of 1".

Fig. 8. - Note cross-sections of non-woody axes. Mag. 3.5X. A longitudinal section of bore 476 between 1-2".

PLATE III

FIG. 5

FIG. 6

FIG. 7

FIG. 8

PLATE IV

Fig. 9. - Note slight compaction of fine fibrous elements. Mag. 3.5X. Cross-section of bore 476 at depth of 2".

Fig.10. - Oblique cuts through non-woody axial material is shown. Mag. 3.5X. Longitudinal section of bore 476 between 2 - 3".

Fig.11. - In left top corner, a good example of leafy material which looks like a hollow stem. Mag. 3.5X. Cross-section of bore 476 at depth of 3".

Fig.12. - Density increase very apparent. Mag. 3.5X. Longitudinal section of bore 476 between 3-4".

PLATE IV

FIG. 9

FIG.10

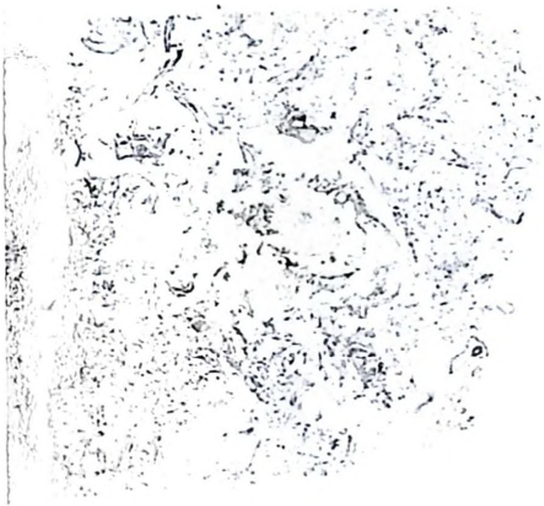


FIG.11

FIG.12

PLATE V

Fig. 13. - Note density increase. Mag. 3.5X. Cross-section of bore 476 at depth of 4".

Fig. 14. - Note cross-sections of axial material. Mag. 3.5X. Longitudinal section of bore 476 between 4 - 5".

Fig. 15. - Mag. 3.5X. Cross-section of bore 476 at depth of 5".

Fig. 16. - Mag. 3.5X. Longitudinal section of bore 476 between 5 - 6".

PLATE V

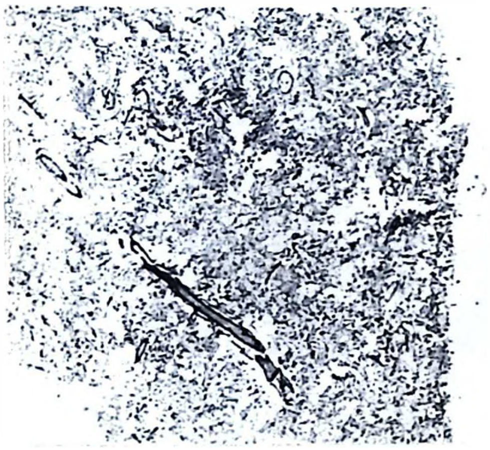


FIG.13

FIG.14

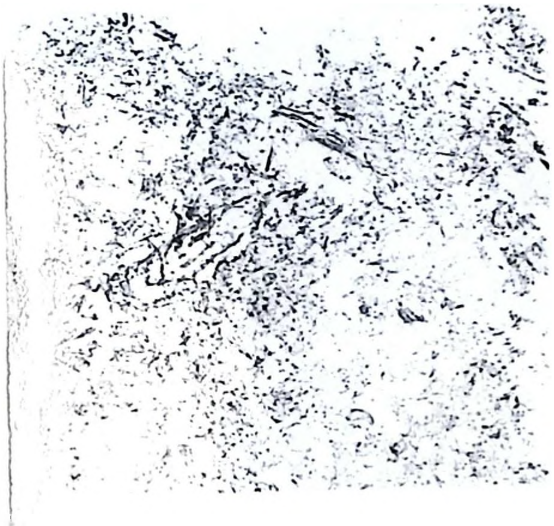


FIG.15

FIG.16

PLATE VI

Fig. 17. - Mag. 3.5X. Cross-section of bore 476 at depth of 6".

Fig. 18. - Mag. 3.5X. Longitudinal section of bore 476 between 6 - 7".

Fig. 19. - Note crowding of non-woody material. Mag. 3.5X. Cross-section of bore 476 at depth of 7".

Fig. 20. - Note density increase. Mag. 3.5X. Longitudinal section of bore 476 from 7 - 8".

PLATE VI

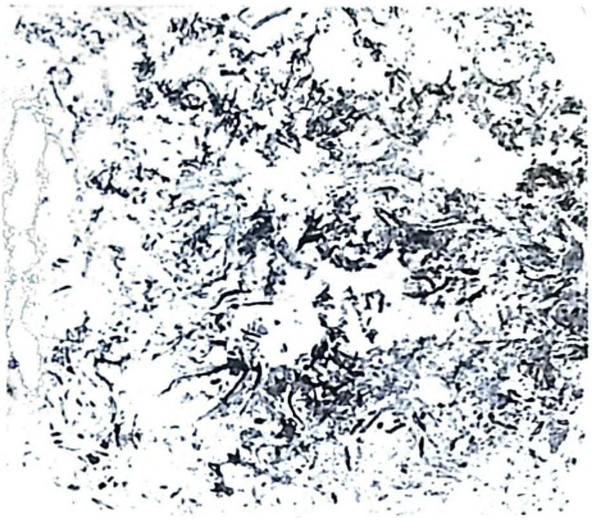


FIG.17

FIG.18

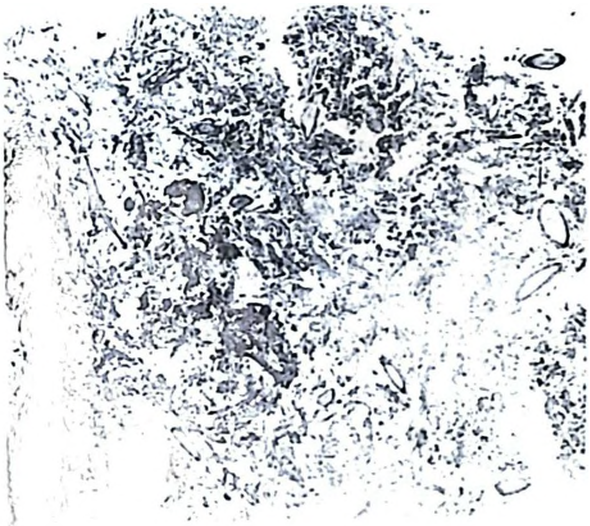


FIG.19

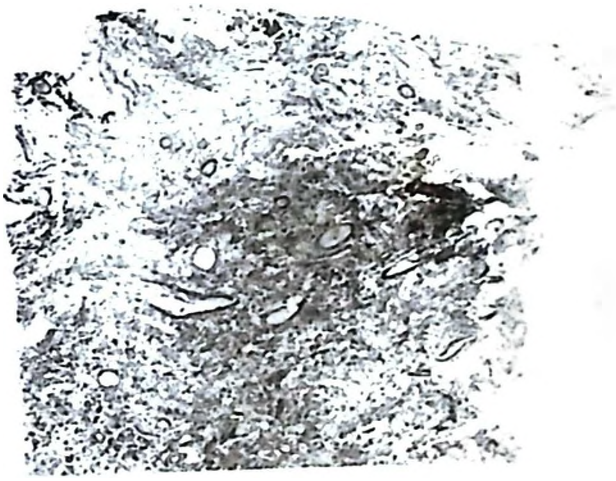


FIG.20

PLATE VII

Fig. 21. - Note density, and also apparent absent, though not actual absence of axial material. Mag. 3.5X. Cross-section of bore 476 at a depth of 8".

Fig. 22. - Note density at bottom of bore. Mag. 3.5X. Longitudinal section of bore 476 between 8 - 9".

PLATE VII

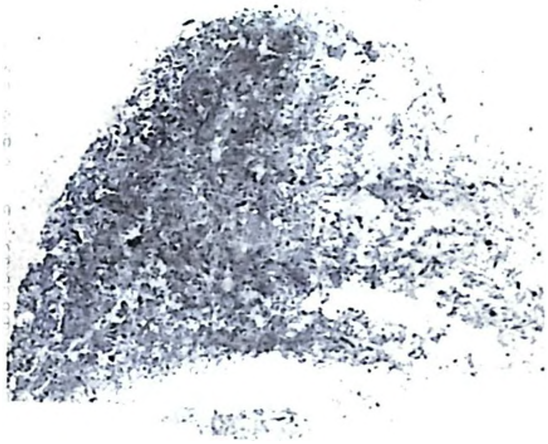


FIG.21

FIG.22

PLATE VIII

Fig. 23. - Note the small amount of material present. Mag. 3.5X. Cross-section of bore 475 at surface.

Fig. 24. - Note density increase with depth. Mag. 3.5X. Longitudinal section of bore 475 between 0 - 1".

Fig. 25. - Note increase in density, yet spaces are still present. Mag. 3.5X. Cross-section of bore 475 at depth of 1".

Fig. 26. - The relative abundance of cross-sections of the woody axes to the longitudinal ones should be noticed. Mag. 3.5X. Longitudinal section of bore 475 between 1 - 2".

PLATE VIII

FIG.23

FIG.24

FIG.25

FIG.26

PLATE IX

Fig. 27. - Density of woody material increased. Mag. 3.5X. Cross-section of bore 475 ad depth of 2".

Fig. 28. - Woody material shows some suggestion of layering. Mag. 3.5X. Longitudinal section of bore 475 between 2 - 3".

Fig. 29. - A good example of the arrangement of the woody material, especially the abundance of longitudinal sections of the woody axes. Mag. 3.5X. Cross-section of bore 475 at depth of 3".

Fig. 30. - Mag. 3.5X. Longitudinal section of bore 475 between 3 - 4".

PLATE IX

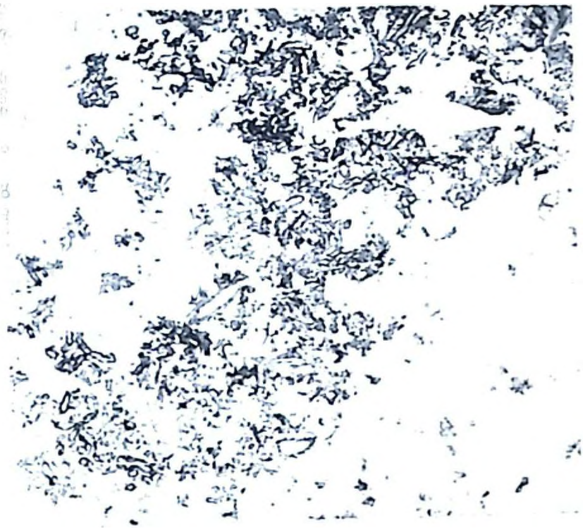


FIG.27

FIG.28

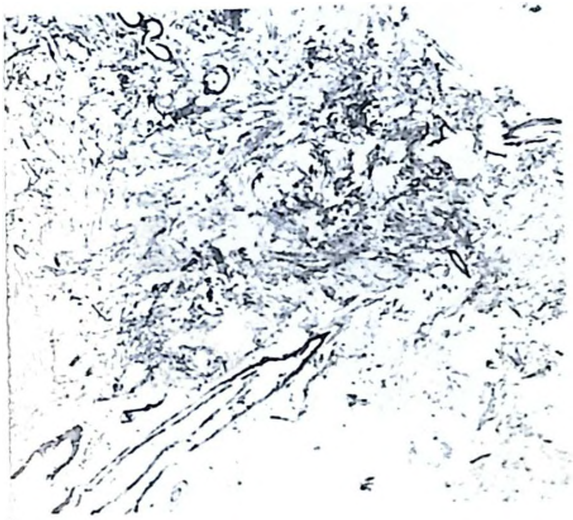


FIG.29

FIG.30

PLATE X

Fig. 31. - Dense woody material. Mag. 3.5X. Cross-section of bore 475 at a depth of 4".

Fig. 32. - Mag. 3.5X. Longitudinal section of bore 475 between 4 - 5".

Fig. 33. - Mag. 3.5X. Cross-section of bore 475 at a depth of 5".

Fig. 34. - An example of the greatest density found in bore 475. Mag. 3.5X. Longitudinal section of bore 475 between 5 - 6".

PLATE X

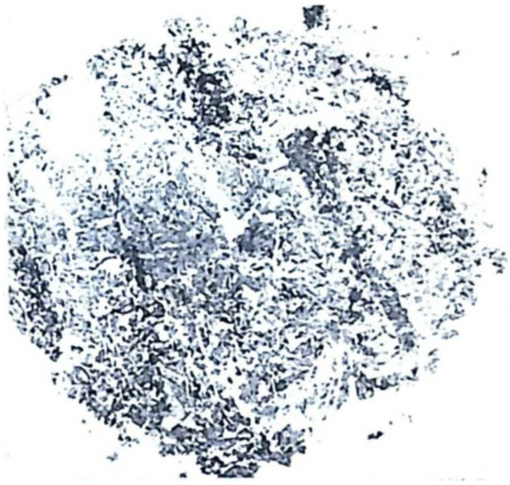


FIG.31

FIG.32

FIG.33

FIG.34

PLATE XI

Fig. 35. - Shows presence of bordered pits. Mag. 326X. Bore 475, depth 3".

Fig. 36. - Cross-section of woody stem. Mag. 67X. Bore 475, depth 3".

Fig. 37. - Group of pollen grains. Mag. 67X. Bore 475, depth 3".

Fig. 38. - Pollen grains. Mag. 67X. Bore 475, depth 5".

Fig. 39. - Cross-section of root. Mag. 67X. Bore 475, depth 2".

Fig. 40. - Group of pollen grains. Mag. 67X. Bore 475, depth 2".

Fig. 41. - Cross-section of spruce needle. Mag. 67X. Bore 475, depth 1".

Fig. 42. - Unidentified pollen grain. Mag. 326X. Bore 475, depth 5".

Fig. 43. - Example of cuticle and bark. Mag. 67X. Bore 475, depth 4".

PLATE XI


35


36


37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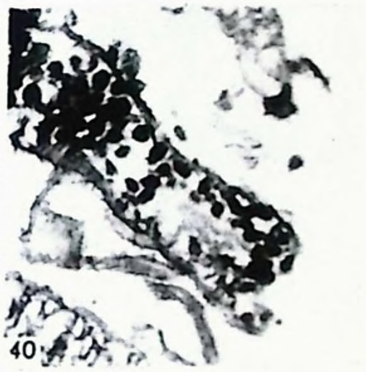
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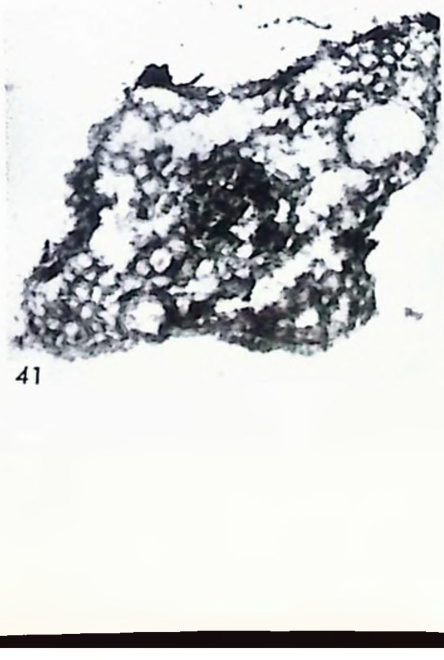
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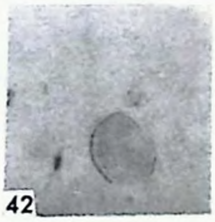
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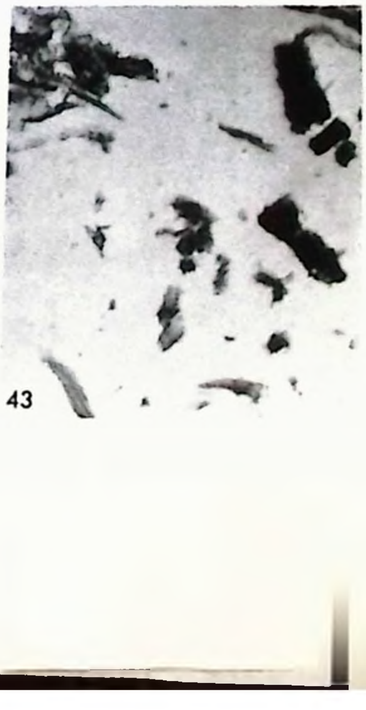
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PLATE XII

Fig. 44. - Longitudinal section of woody material. Mag. 67X. Bore 475, depth 4".

Fig. 45. - Lignified wood. Mag. 67X. Bore 475, depth 5".

Fig. 46. - Cross-section of a woody stem. Mag. 67X. Bore 475, depth 5".

Fig. 47. - Longitudinal section of non-woody stem. Mag. 67X. Bore 476, depth 1".

Fig. 48. - Stem with branches. Mag. 67X. Bore 476, depth 1".

Fig. 49. - Perithecium of Phyllactina. Mag. 67X. Bore 476, depth 1".

Fig. 50. - Cross-section of stem of water plant. Mag. 67X. Bore 476, depth 1".

Fig. 51. - Cross-section of stem. Mag. 67X. Bore 476, depth 2".

Fig. 52. - Pollen grain. Mag. 67X. Bore 476, depth 2".

PLATE XII


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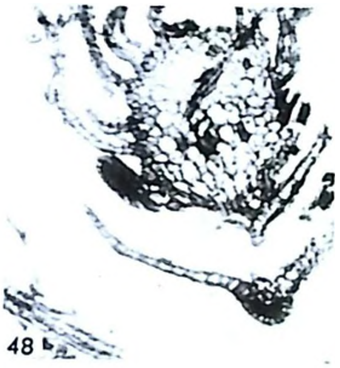
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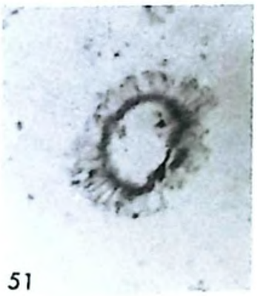
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PLATE XIII

Fig. 53. - Oblique section of non-woody leaf. Mag. 67X. Bore 476, depth 4".

Fig. 54. - Oblique section of non-woody leaf. Mag. 67X. Bore 476, depth 2".

Fig. 55. - Tentatively identified as axial material. Mag. 67X. Bore 476, depth 4".

Fig. 56. - Detail of non-woody leaf. Mag. 320X. Bore 476, depth 2".

Fig. 57. - Axial cross-section. Mag. 67X. Bore 476, depth 4".

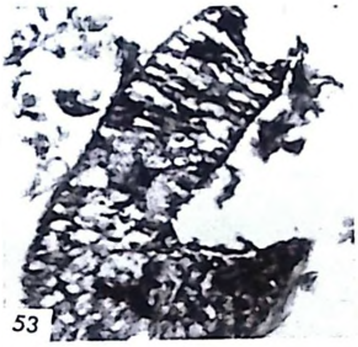
Fig. 58. - Longitudinal section of non-woody leaf. Mag. 67X. Bore 476, depth 2".

Fig. 59. - Longitudinal section of non-woody stem with branches. Mag. 67X. Bore 476, depth 2".

Fig. 60. - Cross-section of water plant stem. Mag. 67X. Bore 475, depth 3".

Fig. 61. - Cross-section of water plant stem. Mag. 67X. Bore 475, depth 2".

PLATE XIII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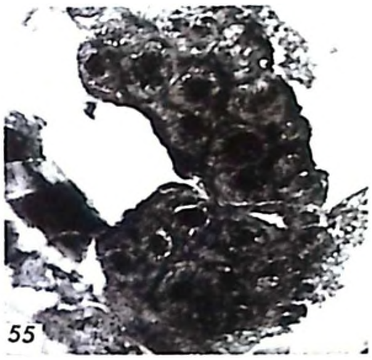
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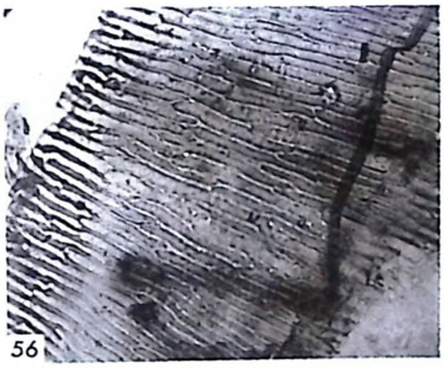
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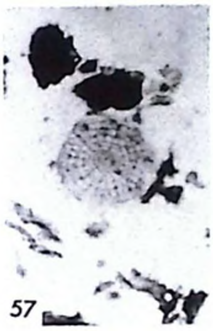
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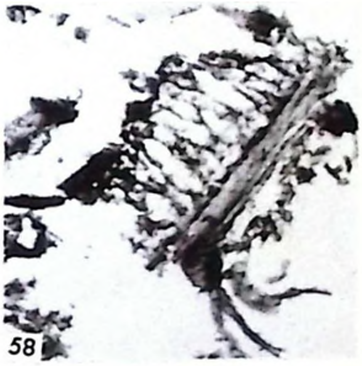
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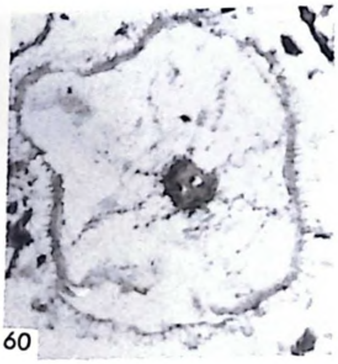
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PLATE XIV

Fig. 62. - Non-woody leafy tissue. Mag. 67X. Bore 476, depth 3".

Fig. 63. - Cross-section of non-woody leaf group. Mag. 67X. Bore 476, depth 3".

Fig. 64. - Longitudinal section of non-woody axial material showing cellular construction. Mag. 67X. Bore 476, depth 4".

Fig. 65. - Oblique section of leafy material. Mag. 67X. Bore 476, depth 3".

Fig. 66. - Longitudinal section of non-woody axial material. Mag. 67X. Bore 476, depth 3".

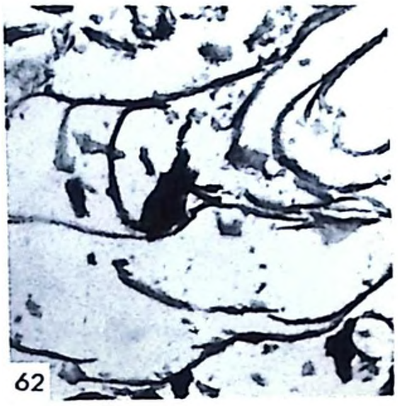
Fig. 67. - Tracheids show up clearly in this longitudinal section of non-woody axial material. Mag. 67X. Bore 476, depth 5".

Fig. 68. - Cross-section of non-woody axis. Mag. 67X. Bore 476, depth 4".

Fig. 69. - Perithecium of Phyllactinia, lacking appendages. Mag. 67X. Bore 476, depth 4".

Fig. 70. - Amorphous granular particles. Mag. 67X. Bore 476, depth 5".

PLATE XIV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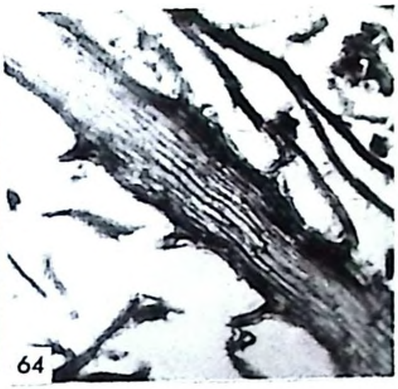
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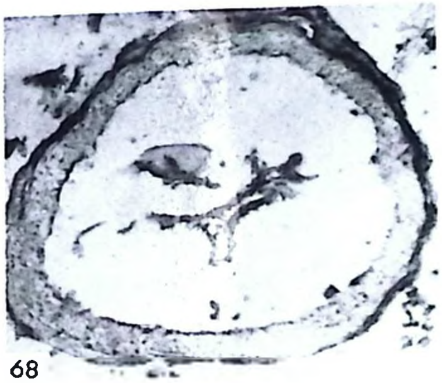
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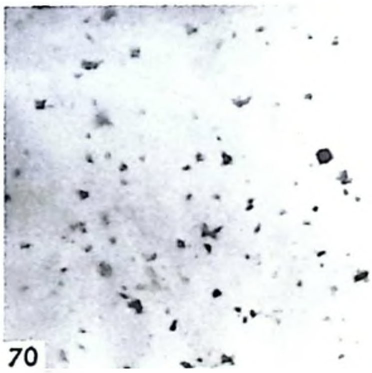
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