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A Study of Certain Organic Compounds of the Bottom Sediments of the Dundas Marsh, Hamilton, Ontario

by

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A Thesis

Submitted to the Faculty of Arts and Sciences

in Partial Fulfilment of the Requirements

for the Degree

Master of Science

McMaster University

September 1951

The author of this thesis holds the following degree:

Bachelor of Science, Honour Chemistry, 1949 (McMaster)

This thesis was prepared under the supervision of:

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Scope and contents of this thesis:

In the course of a little over a year, from January, 1950, to March, 1951, core samples of bottom sediments were collected at three different stations in the Dundas Marsh, Hamilton, Ontario. A number of the samples were analysed for total carbon content, bitumen, pectins, hemicelluloses, and cellulose and lignin content.

This study is part of a larger investigation by the Department of Zoology to ascertain the relationships between the biological productivity in lakes and the rate of mineralization of the organic detritus in lake bottom sediments.

Acknowledgements

The study involved in this thesis has been made possible through the willing cooperation of many people. I wish to express my sincere appreciation to those who have aided the work, both in the field and in the laboratory. The laboratory phase of this program was made possible through the facilities of McMaster University.

I also wish to express my indebtedness to Dr. Herman Kleerekoper of McMaster University, who first introduced me to this study, and under whose guidance it has been completed.

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Chapter I INTRODUCTION

Scope of the investigation

Our knowledge regarding the factors which determine the biological productivity in inland waters is very incomplete. Considerable information regarding the relationships between the thermal and chemical aspects of stratification in lakes has become available in the past thirty years or so, namely through the work done by A. Thienemann (1926 and his school, as well as by a number of other workers - Ruttner (1931), Alsterberg (1927), Naumann (1922), Birge and Juday (1927), to mention just a few. It is also well understood at the present that the availability of nutrients in the water is one of the decisive factors which determine the biological productivity of the environment. In this respect, there is considerable similarity between the conditions observed in soils and those in lake water.

Our knowledge is much less complete, however, with respect to the fate of the chemical elements incorporated in the bodies of the phytoplankton and zooplankton developed in the lake waters. The work of Birge and Juday and their followers gave us detailed information on the chemical composition of plankton organisms in a number of lakes in Wisconsin. Other workers provided us with similar information on the chemical composition of marine plankton. Furthermore, in recent years, considerable attention has been given to the processes of decomposition in marine plankton, and to the microbiological activites related to these processes. Much less is known in this respect on conditions in the fresh water environment. Decaying organisms and the

coprogenic forms of decay finally arrive at the bottom of the lake where they are further submitted to processes of decomposition in which bacterial activities are instrumental. This biological decomposition, plus a certain amount of chemical oxidation, produce the sediment found at the bottom of the lake. This sediment has a chemical composition which varies evidently with the intensity of the processes of decomposition just mentioned. In some lakes the decomposition of the plankton cadavers is rapid and often thorough, resulting in the liberation of the valuable minerals which were part of the complex organic substances forming the living matter of the organisms. In other lakes the decomposition of these decaying substances might be much slower and less complete thus giving origin to a type of sediment which contains varying amounts of incompletely hydrolyzed organic substances. These organic substances, therefore, contain amounts of minerals which can only be made available to new generations of plankton organisms after further decomposition or mineralization of the organic compounds in these sediments.

In the first instance, where the organic substances were mineralized quickly and thoroughly, the liberated minerals will be returned to the main body of the lake at the first period of total circulation, which is normally the fall over-turn in the case of a thermically stratified lake. In such conditions the accumulation of minerals in the lake bottom sediment is slow and a small amount of minerals brought in from the surroundings of the lake by ground water, run-off or wind-borne materials will suffice to keep the level of productivity relatively constant.

In the second type of lake, however, incomplete mineralization of decaying organisms produced in the lake results in a slow and continuous accumulation of minerals in the lake sediments, so that, unless a constant and considerable supply from the surroundings is available, biological productivity will have to decrease in the course of the years because of depletion of nutrients. This depletion, of course, will affect the productivity. The nutrients affected in the first place will be those which were nearest to the minimal concentrations.

The rate of decomposition of organic material in lakes is, therefore, fundamentally one of biological productivity and should be considered at the present as one of the most important problems to be tackled in limnology.

In spite of its importance very little information has been gathered on the processes involved in the mineralization of organic matter in lakes and on the environmental conditions which affect these processes. The importance of the problem has been recognized by a number of other workers - Naumann (1920), Lundqvist (1924) and others.

In the present study an attempt has been made to approach this problem by investigating quantitatively some of the substances which are formed in the course of the decomposition of the organic detritus. It is evident that mineralization will start with those substances which are of little chemical stability; this if followed by mineralization of the more stable compounds. Finally, substances highly resistant to decomposition remain in the sediment, subjected

or not to further mineralization. It is doubtful that in any of these groups of substances mineralization occurs in one final step. It has been shown for certain organic substances that the final end-product of mineralization is reached in a number of steps which produce intermediate compounds of varying chemical stability. Some of these compounds are better known and are characteristic of certain phases of mineralization. These aspects have been studied mainly by geochemists, geologists and chemists such as Souci (1938), Oden (1919), Gams (1921 and 1930), and Potonie (1910) interested in the composition of combustible organogenic deposits.

By determining quantitatively some of these intermediate compounds in the organogenic sediments of Dundas Marsh, an attempt was made to contribute to our knowledge on the rate of intensity of mineralization of these deposits at different levels in the sediment of the marsh. In planning this investigation it was considered that the organic substances to be found in the sediments could be placed in two main groups. The first group would represent those substances which entered the sediment unmodified, and which may be considered as the organic building stones of the sediment. In this group belong substances like proteins, celluloses, small amounts of mono-disaccharides, hemi-celluloses, pectins, lignih, fats, proto-bitumen, polymer proto-bitumen and ferments.

In the second group of substances are placed those which are the intermediate or final products of the mineralization of the substances belonging to the first group. Such are humus substances like humic acids, humo-lignic acids, humic substances in general; bitumen,

pentoses, amino-acids and proteins. The latter are formed anew by the bacteria participating in the decomposition of the organic matter. This was investigated by Allgeier, Peterson, and Juday (1934), Birge (1932) and Weeks (1944).

In this investigation only a small number of the above mentioned substances were analyzed in addition to the amount of total carbon present. This investigation was supported by a grant for research received by Dr. H. Kleerekoper from the Research Council of Ontario.

A review of some of the literature

As previously stated, very little information has been gathered on the processes involved in the mineralization of organic matter in lakes.

Steiner and Meloche (1935) in their study of lake muds found 30 to 48% of the total organic matter was lignin. The percentage of carbon in the lignin which had undergone the least decomposition approached the high value of 64%.

Hutchinson and Wollack (1940) working on Linsley Pond found variations in lignin between 1.1% at a depth of 43 feet to 71.5% at a depth of 30 feet. The loss on ignition was found to range between 2.9% and 59.0% with respect to the previously mentioned depths. These same workers investigated the sediments of lakes in Indian Tibet and found lignin values ranging from 1.34 to 4.16% of the dry sediment.

In the sediments of Trout Lake, analysed by Twenhofel, McKelvey, Nelson and Feray (1945), the mean lignin value was 23.29% of the dry sediment. The top of the core and hence the surface sediment contained the least lignin.

Chapter II METHODS AND MATERIALS

Sampling devices and collection of samples

Surface samples were taken at all stations (fig. 1) using the Lundqvist sampler. The tubes in this apparatus were 45.5 cm. long with an inside diameter of 2 cm. Deeper cores were taken at station 1 (fig. 2) using the Davis sampler and at stations 2 (fig. 3) and 3 (fig. 4) using the Miller sampler. The Davis sampler cut a core of sediment 38.64 cm. long; whereas the Miller sampler gave a core 50 cm. long and 2.8 cm. in diameter (Table 1)

During the open water season, all samples were taken from a boat. During the winter, holes were drilled through the ice cover for the collection of samples.

Each core was divided into several portions according to variations in colour, general macroscopic aspect and presence of fossils, and placed into glass jars. The presence of hydrogen sulphide was noted by odour. A small amount of chloroform was added to each sample jar to retard further decomposition.

Upon arrival at the laboratory, a small amount of each sample was washed with distilled water and examined under the microscope for fossils. These were shipped to Dr. Harry Van der Schalie, of the University Museum, University of Michigan, for identification. Microscopic slides were made of a number of the samples using glycerine jelly as a medium and formaldehyde as a preservative (fig. 8 to 13). Samples were stored in the refrigerator until analysed. The substances analysed and the sequence of the analyses are shown

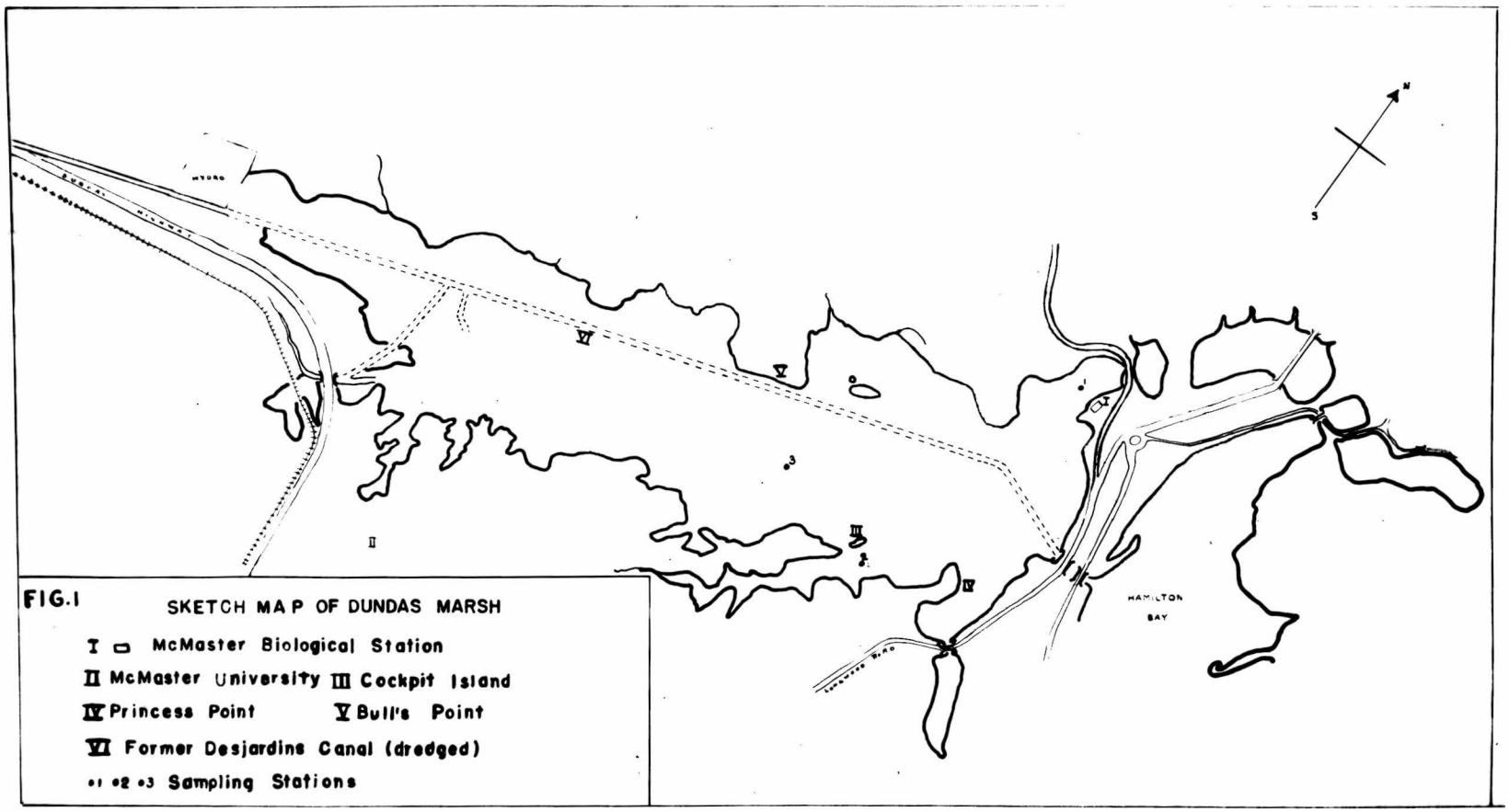


FIG.1 SKETCH MAP OF DUNDAS MARSH

I ▭ McMaster Biological Station

II McMaster University III Cockpit Island

IV Princess Point V Bull's Point

VI Former Desjardins Canal (dredged)

•1 •2 •3 Sampling Stations

Figure 2

Station 1

Located in a south-easterly direction, directly out from the McMaster University Biological Station (I, fig. 1), half way between it and the opposite shore. The average water depth was 1.1 meters.

Figure 3

Station 2

Situated in a westerly direction, half-way between the southern end of Cockpit Island (III, fig. 1) and Princess Point (IV, fig. 1). The average water depth was 4.4 meters.

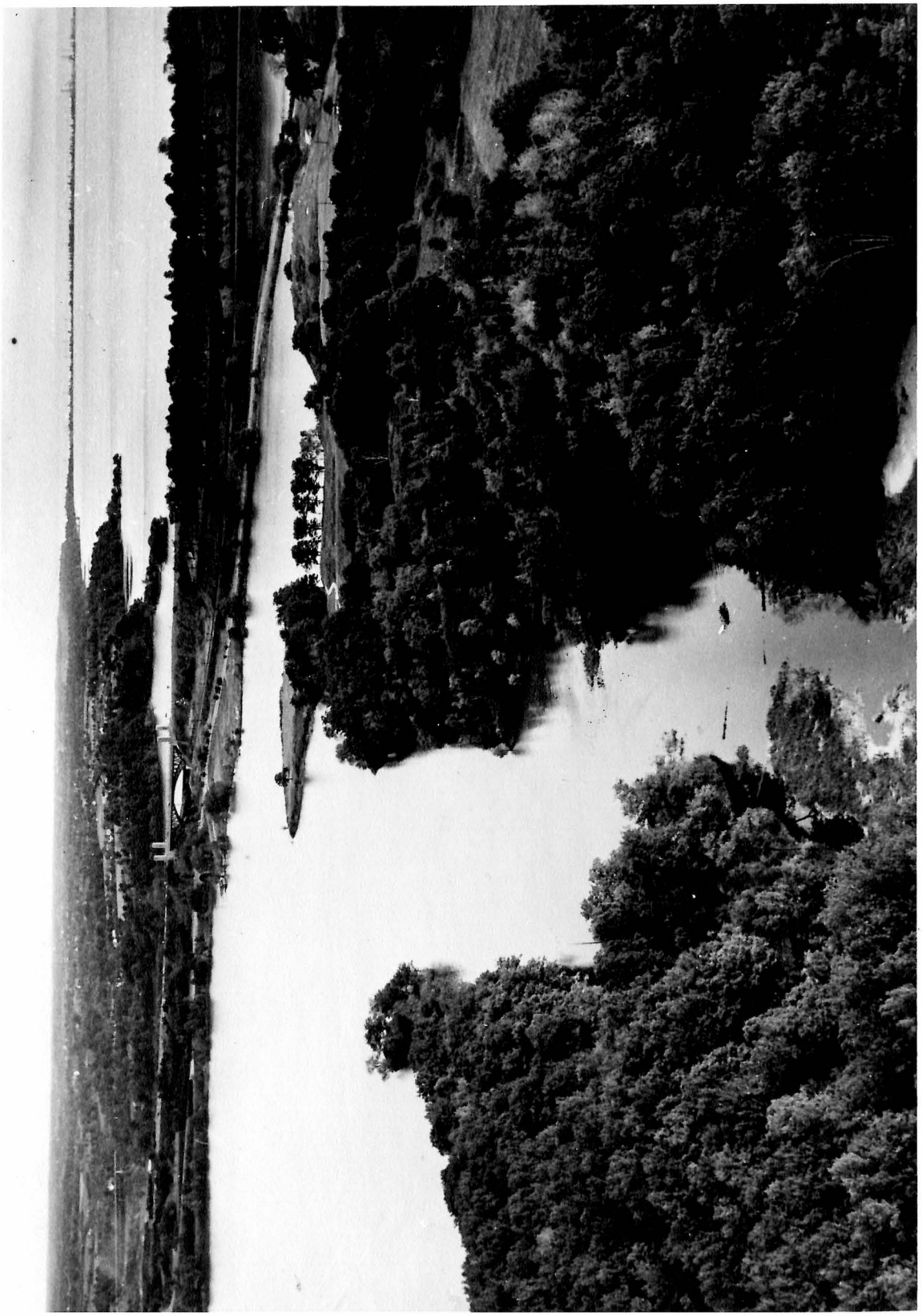


Figure 4

Station 3

Located in a southeasterly direction from the western tip of Bull's Point (V, fig. 1), half-way between the southwest markers of the former Desjardins Canal (VI, fig. 1) and the southwest shore. The average water depth was 1.4 meters.

Table 1

Date of sampling	Number of station and number of samples collected	Depth of water in meters	Sampling device	Sample numbers
1/3/50	1 (1)	1	Lundqvist	A1
3/3/50	1 (3)	1	Lundqvist	A2.1, A2.3, A3, A4
6/3/50	1 (1)	1	Long pipe 5L tubes	A5.1, A5.2, A5.3
6/3/50	1 (2)	1	Lundqvist	A6.1, A6.2, A7.1, A7.2
7/3/50	1 (7)	1	Davis	A8, A9, A10, A11, A12, A13, A14
30/1/51	2 (4)	1.1	Hiller	A15, A16.1, A16.2, A17, A18
31/1/51	3 (4)	1.1	Hiller	A19.1, A19.2, A20.1, A20.2, A21, A22

Date of sampling	Number of station and number of samples collected	Depth of water in meters	Sampling device	Sample numbers
9/2/51	2 (10)	1.26	Hiller	A23, A24.1 A24.2, A25, A26, A27, A28, A29, A30, A31, A32.1, A32.2
16/4/51	3 (1)	1.6	Lundqvist	A33.1, A33.2
16/4/51	2 (1)	1.7	Lundqvist	A34.1, A34.2
16/4/51	1 (1)	1.75	Lundqvist	A35

x = Lundqvist

in fig. 5 in solid line. The following procedures were adopted as described by S. W. Bouci (1938) with the exception of the determination of total carbon.

Preparation of samples

The sample was removed from the refrigerator, and its wet weight determined. The dishes containing the samples were dried in an oven at 105°C. until constant weight (a change of less than 1/10 of 1% in two successive weighings) was obtained. This is the dry weight of the sample used in the calculation of the percentage of water content. The sediment was pulverized with a mortar and pestle and dried at 105°C. in a 50 ml. beaker.

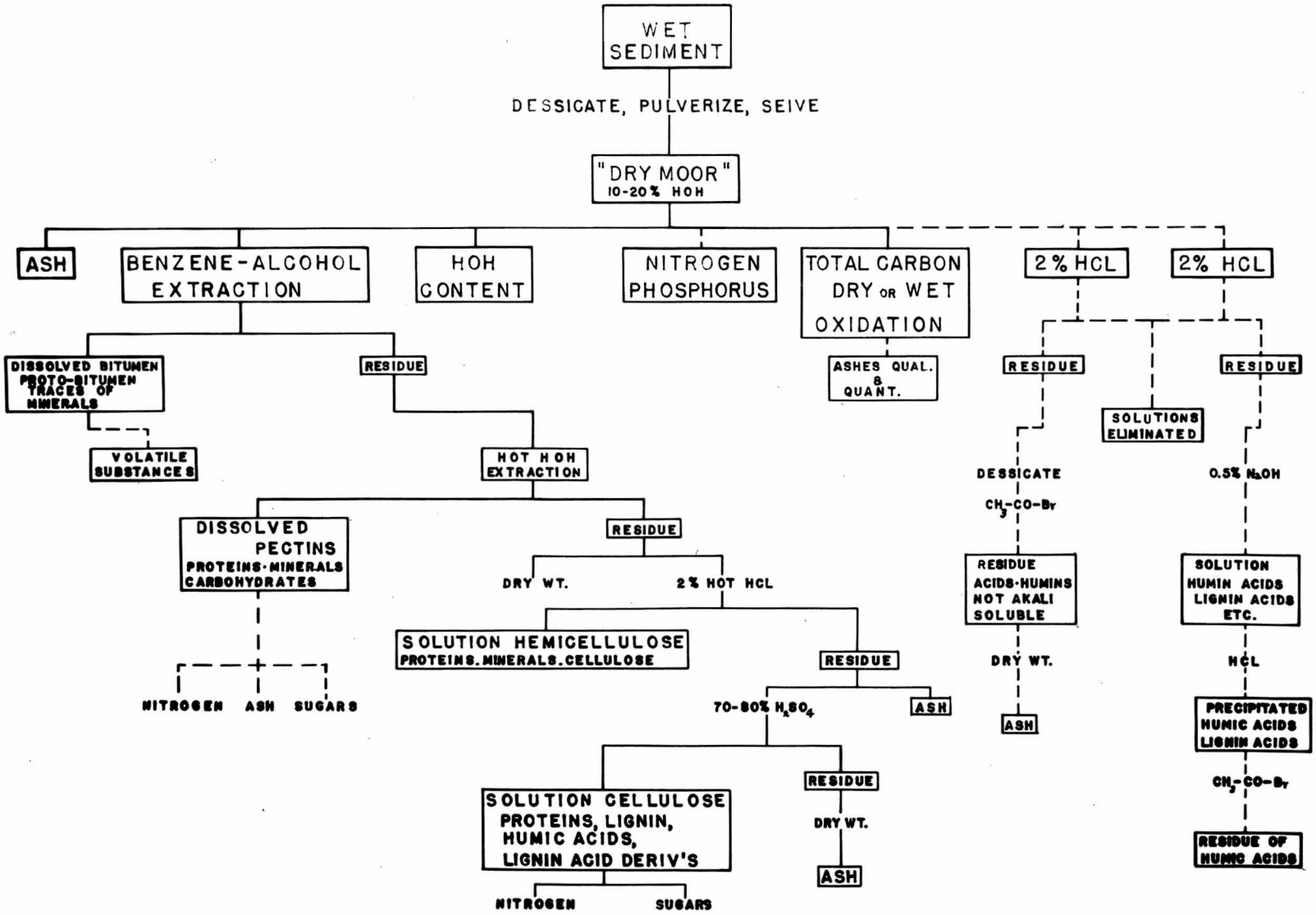

WET SEDIMENT
DESSICATE, PULVERIZE, SEIVE
"DRY MOOR" 10-20% HOH
ASH
BENZENE-ALCOHOL EXTRACTION
HOH CONTENT
NITROGEN PHOSPHORUS
TOTAL CARBON DRY OR WET OXIDATION
2% HCL
2% HCL
DISSOLVED BITUMEN PROTO-BITUMEN TRACES OF MINERALS
RESIDUE
ASHES QUAL. & QUANT.
RESIDUE
RESIDUE
SOLUTIONS ELIMINATED
VOLATILE SUBSTANCES
HOT H OH EXTRACTION
DESSICATE
CH_3-CO-Br
0.5% N_aOH
DISSOLVED PECTINS PROTEINS-MINERALS CARBOHYDRATES
RESIDUE
DRY WT.
2% HOT HCL
RESIDUE ACIDS-HUMINS NOT AKALI SOLUBLE
SOLUTION HUMIN ACIDS LIGNIN ACIDS ETC.
SOLUTION HEMICELLULOSE PROTEINS. MINERALS. CELLULOSE
RESIDUE
DRY WT.
HCL
NITROGEN
ASH
SUGARS
70-80% H_2SO_4
ASH
ASH
PRECIPITATED HUMIC ACIDS LIGNIN ACIDS
RESIDUE
CH_3-CO-Br
SOLUTION CELLULOSE PROTEINS, LIGNIN, HUMIC ACIDS, LIGNIN ACID DERIV'S
DRY WT.
RESIDUE OF HUMIC ACIDS
ASH
NITROGEN
SUGARS

FIG. 5

Lignin and related compounds

Analyses for lignin and compounds similar to lignin in the sediment were carried out under a step-by-step procedure as outlined in the following pages.

a. Determination of ash

Approximately two grams of the dry sediment were weighed in a silica crucible and incinerated in a muffle furnace at 660°C. for one hour. The crucible and ash were removed from the furnace, cooled in a vacuum dessicator and weighed. The weight of the ash (A), percentage ash (%A), and loss on ignition were calculated.

b. Substances soluble in benzene-alcohol solution (bitumen, proto-bitumen and fats)

Approximately ten grams of the dry sediment were extracted to exhaustion in a soxhlet extraction flask using a mixture of equal parts of benzene and absolute alcohol. The end point of the extraction was reached when the returning solvent became colourless or only slightly yellowish. The solution containing the benzene-alcohol soluble substances was transferred to a weighed silica crucible, dried in the oven at 105°C., cooled in a vacuum dessicator and weighed. An ash determination of this dry material was carried out (see Determination of ash).

The calculation of D (organic substances soluble in benzene alcohol in percent of dry sediment) was as follows,

$$D = \frac{100 \cdot (C - A_1)}{B}$$

C weight of benzene-alcohol soluble substances in grams

A_1 ash weight of benzene-alcohol soluble substances in grams

B weight of the original dry sediment in grams

The residue in the extraction apparatus, (insoluble in benzene-alcohol) was dried to constant weight at 105°C. (C_1)

c. Substances soluble in hot water (pectins, soluble carbohydrates, proteins and minerals)

About four grams of the dry residue, insoluble in benzene-alcohol was weighed in a 50 ml. beaker and quantitatively washed with distilled water into a one liter florence flask. Distilled water was added to the flask in small quantities with thorough mixing, to make a total volume of 300 ml. A liebig condenser was attached to the flask and the mixture of sediment and water refluxed for three hours. By this process mostly pectins, as well as smaller quantities of minerals, soluble proetins and soluble carbohydrates, including starch, were dissolved. The mixture of sediment and water was filtered through a fritted glass crucible of medium coarseness and washed for a short time with hot water. In an aliquot of the filtrate the content of minerals was determined by drying at 105°C. and incineration at 660°C. The crucible containing the material insoluble in hot water, was placed in a wide mouthed weighing bottle and dried at 105°C. to constant weight.

The content of the organic substances soluble in hot water (F) in percent of dry material was calculated as follows,

$$F = (K - C_2 - A_2) \cdot \frac{C_1}{K} \cdot \frac{C_1}{B} \cdot 100$$

K fraction of material in grams insoluble in benzene-alcohol (C_1)

C_2 material in grams insoluble in hot water and benzene-alcohol

A_2 inorganic material soluble in hot water but insoluble in benzene-alcohol

C_1 material in grams insoluble in benzene-alcohol

B the weight of the dry sediment in grams

d. Substances hydrolyzable with dilute acids (hemicellulose, proteins and small amounts of cellulose)

A part (K_1) of the material insoluble in hot water, (C_2), was quantitatively transferred into a one liter florence flask and refluxed for three hours with 300 ml. of two percent hydrochloric acid. The hemicellulose was thereby hydrolyzed. This dissolves small parts of cellulose as well as protein, acid soluble minerals and perhaps uric acid, plus other pectins still remaining after the preceding determination. The precipitate was filtered through a fritted glass crucible of medium coarseness, washed with hot water until free of acids, placed in a wide-mouthed weighing bottle, and dried to constant weight at 105°C. Of this precipitate, insoluble in dilute acid, 0.6 grams was used for the determination of the ash content by incineration at 660°C. The calculation was as follows,

$$G = \left(\frac{C_1}{K} \cdot \frac{C_2}{K_1} \cdot (K_1 - C_3) \cdot \frac{C_1}{B} \cdot 100\right) - (A - (A_1 + A_2) - A_3)$$

G organic material, in percent of dry sediment (B), soluble in dilute acids, not hydrolyzable in hot water and insoluble in benzene-alcohol

C_1 material in grams insoluble in benzene-alcohol

K fraction of material in grams insoluble in benzene-alcohol (C_1)

C_2 material in grams not hydrolyzable in hot water

K_1 fraction of the material in grams not hydrolyzable in hot water (C_2) employed in the hydrolysis with dilute acid

C_3 material in grams not hydrolyzable in dilute acid

B weight of the dry sediment in grams

A inorganic material in percent of the dry sediment (B)

A_1 inorganic material soluble in benzene-alcohol, in percent of the dry sediment (B)

A_2 inorganic material soluble in hot water, but not in benzene-alcohol, in percent of the dry weight (B)

A_3 inorganic material insoluble in dilute hydrochloric acid, hot water and benzene-alcohol in percent of the dry weight (B)

e. Substances hydrolyzable with strong sulphuric acid (celluloses, humic acids, lignin, and small amounts of proteins)

A fraction (K_3) of the material, insoluble in dilute acid, (C_3) was weighed in a weighing bottle and mixed with 20 ml. of 72-80% sulphuric acid. The mixture was left standing at room temperature (20° - 25°C.) for two and a half hours, with repeated stirring. It was then quantitatively washed into a one liter florence flask with 300 ml. of distilled water and refluxed for five hours. By this treatment cellulose in particular, as well as other substances were dissolved and hydrolyzed. As in previous steps (c and d) the mixture was filtered, washed with hot water and dried to constant weight at 105°C. The

material, insoluble in strong sulphuric acid, was used for an ash determination.

From the previously obtained values and from the loss of weight produced by the sulphuric acid treatment, the quantity of dissolved lignin and humic acids was obtained by subtraction. The calculation followed the equation

$$N = \left(\frac{C_1}{K} \cdot \frac{C_2}{K_1} \cdot \frac{C_3}{K_3} \cdot (K_3 - C_4) \cdot \frac{C_1}{B} \cdot 100\right) - (A_3 - A_4)$$

N organic material, in percent of the dry sediment (B), soluble in 72-80% sulphuric acid, though not hydrolyzable with dilute acid and hot water, and not soluble in benzene-alcohol

C_1 material in grams insoluble in benzene-alcohol

K fraction of material in grams insoluble in benzene-alcohol (C_1)

C_2 material in grams not hydrolyzable in hot water

K_1 fraction of the material in grams not hydrolyzable in hot water (C_2) employed in the hydrolysis with dilute acid

C_3 material in grams not hydrolyzable in dilute acid

K_3 fraction of the material in grams hydrolyzable in dilute acid, (C_3), used in the hydrolysis with 72-80% sulphuric acid

C_4 substances, in grams, insoluble with 72-80% sulphuric acid

B the weight of the dry sediment in grams

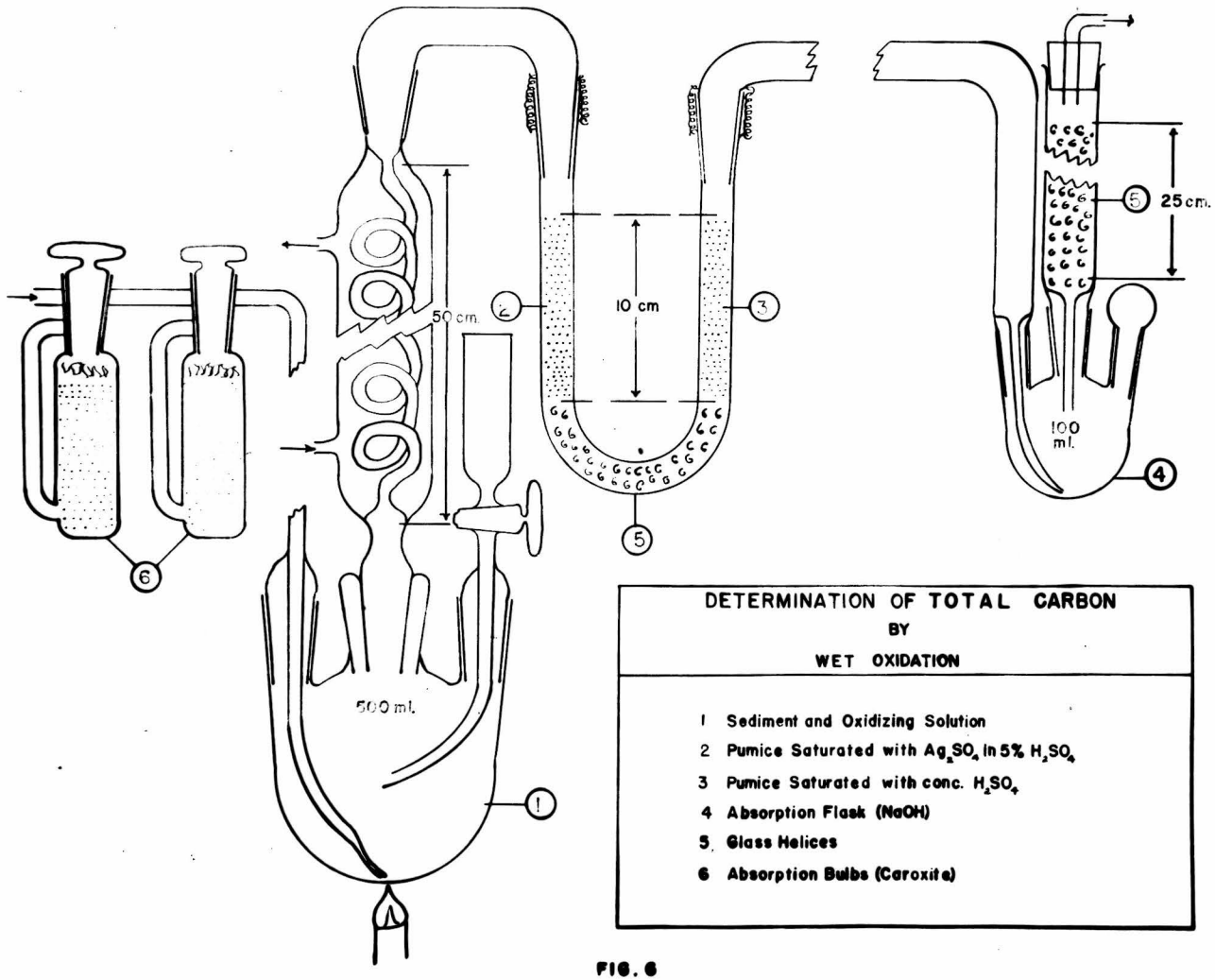
A_3 inorganic material insoluble in dilute hydrochloric acid, hot water and benzene-alcohol in percent of the dry sediment (B)

A_4 inorganic material insoluble in 72-80% H_2SO_4, 2% HCl, hot water and benzene-alcohol in percent of the dry sediment (B)

Total carbon

For the determination of total carbon the apparatus shown in fig. 6 was used. Air was drawn into the system through two absorption bulbs (6) and glass tubing reaching to the bottom of the flask (1), ₹ 24/40, 35/45, 24/40. The flask was joined by means of a reducing adapter to a Graham condenser with ₹ 24/40, 24/40 joints. A separatory funnel with a ground glass joint, ₹ 24/40, filled the remaining neck of the flask (1). All ground glass joints of the flask (1) and condenser were sealed with phosphoric acid saturated with phosphorous pentoxide, whereas all other joints were sealed with silicone grease. The U-tube, ₹ 19/38, 19/38, containing pumice((2)and 3)) and helices (5) was sealed onto glass tubing that reached to the bottom of the absorption flask (4) having ₹ 19/38, 24/40, 19/38 joints. The vacuum line was attached to the center neck of the flask (4) through a glass tube filled with helices (5). The third neck of the flask (4) was stoppered.

Approximately 100 milligrams of the dry sediment were placed in flask (1) and 10 milliliters of an oxidizing solution introduced through the separatory funnel. The oxidizing solution consisted of 85 grams of chromic anhydride in 100 milliliters of water, made up to 250 milliliters with 85% phosphoric acid. Gentle suction was applied and 40 milliliters of a mixture of equal parts of phosphoric and sulphuric acids added. The stopcock of the separatory funnel was closed and the flask (1) heated as rapidly as possible without developing pressure within. The gas was drawn out through the condenser and U-tube, the chlorine and sulphite fumes were respectively



DETERMINATION OF TOTAL CARBON
BY
WET OXIDATION

1 Sediment and Oxidizing Solution
2 Pumice Saturated with Ag_2SO_4 in 5% H_2SO_4
3 Pumice Saturated with conc. H_2SO_4
4 Absorption Flask (NaOH)
5 Glass Helices
6 Absorption Bulbs (Caroxite)

FIG. 6

removed respectively by the silver sulphate (2) and the sulphuric acid (3). The carbon dioxide gas was absorbed into 40.00 milliliters of 0.5 N sodium hydroxide solution in flask (4).

After the mixture in the flask had been boiled gently for eighty minutes, the absorption flask was removed and washed down with carbon dioxide free water. The carbon dioxide in the flask was precipitated as barium carbonate by the addition of 10 ml. of 2 N neutral barium chloride solution and the excess alkali titrated with 0.5 N hydrochloric acid solution, using phenolphthalein indicator. The calculation follows, 1 ml. 0.5 N NaOH = 3.0 mg. carbon. (Number of ml. of NaOH added - number of ml. of 0.5 N hydrochloric acid used) x 3 = mg. carbon.

The duration of digestion to total carbon obtained is shown in Table 2.

Table 2

Total reaction time in minutes	Percent of carbon in the dry sediment	Increase in percent of the carbon in the dry sediment
20	5.6	5.6
40	6.4	0.8
60	7.2	0.8
80	7.4	0.2

A few observations on the limnological characteristics of the Dundas Marsh

Since 1946, the Dundas Marsh has been the object of extensive limnological investigations by the Department of Zoology of McMaster University. Some of the data following are quoted from E. Kay's Limnological Studies of the Dundas Marsh Region (thesis for the degree M.A., McMaster, 1949); other data are the results of our own investigation.

The Marsh, called both Coote's Paradise and Dundas Marsh is a very old water basin formed from the receeding waters of Lake Iroquois. It is separated from the western extremity of Lake Ontario by Burlington Heights, an old beach ridge of the Lake Iroquois period of post-glaciation. The area of the marsh is approximately 650 acres, at least half of which is occupied by extensive vegetation. It was formerly bisected by the Desjardins Canal, dredged out in 1837. With the gradual disuse of the canal it has become heavily silted. Spencer's Creek, which enters the marsh through Dundas, is the only water course continuously adding water to the marsh, as other streams become dry beds after the spring floods.

The depth of water in the present vegetation zone is rarely more than a meter. The bottom slopes very gradually to the open water zone, where the deepest areas do not exceed two meters at high water level. The bottom of the open water zone is composed of a silty organic detritus. In the vegetation zone the bottom is a thick mat of organic material.

Though relatively shallow, the marsh has a thermal stratification in summer and evidently both a spring and fall overturn. The temperature of the surface water ranges from 0°C. in winter to 27°C. in summer. Maximum temperatures occur between 4-5 p.m.; minimum temperatures between 3-5 a.m.

Transparency was highest during the late fall and early spring. The dissolved oxygen, during the summer, was found to be above five parts per million at all times. Carbon dioxide was present in minimal amounts and total alkalinity measured in terms of calcium carbonate was between 100 and 210 parts per million. The pH of the marsh water was between 7.0 and 9.2 during the summer.

The zooplankton is abundant, reaching a high peak in spring and dropping sharply in July.

Chapter III RESULTS OF OWN INVESTIGATIONS

Summary of results

(1) The total carbon content of the surface sediments ranged from 6.14% to 6.51% of the dry sediment. (Table 3)

(2) The highest total carbon content of stations 2 and 3 was of samples 90 to 140 cm. below the surface of the marsh bottom. The values ranged from 21.80% at station 2 to 9.66% at station 3. The highest carbon content of station 1 (8.49%), however, occurred in sediment only 27 cm. below the surface of the marsh bottom.

(3) A second high value of total carbon content was noticeable at station 2 (18.61%) at 380 cm., and at station 1 (7.22%) at 303 cm.

(4) The total carbon content of station 2 was highest at almost every depth compared with stations 1 and 3.

(5) The presence of both decomposing flora and fauna in the sediment layers was observed (fig. 8 to 13).

(6) The ash content of all samples taken ranged from 28.08% to 93.04% of the dry sediment. The surface sediments had ash contents ranging from 82.75% to 86.95%. (Table 4)

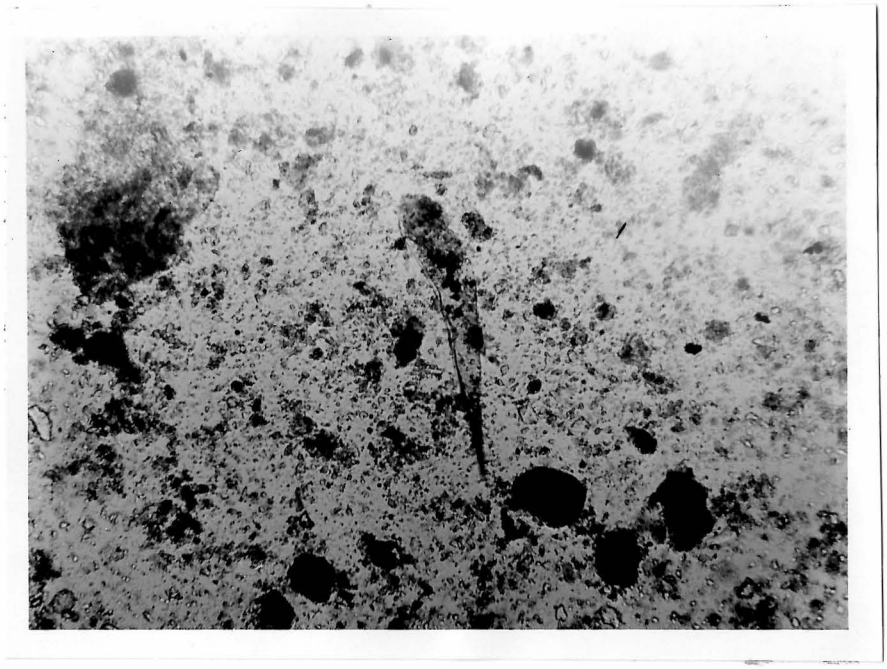
(7) The bitumen, protobitumen and fats (D) of all samples taken, ranged from 0.05% to 7.69% of the dry sediment and the pectins and soluble carbohydrates (F), ranged from 0% to 10.51% of the dry sediment. Hemicelluloses (G) ranged from 0% to 19.99% of the dry

Table 3

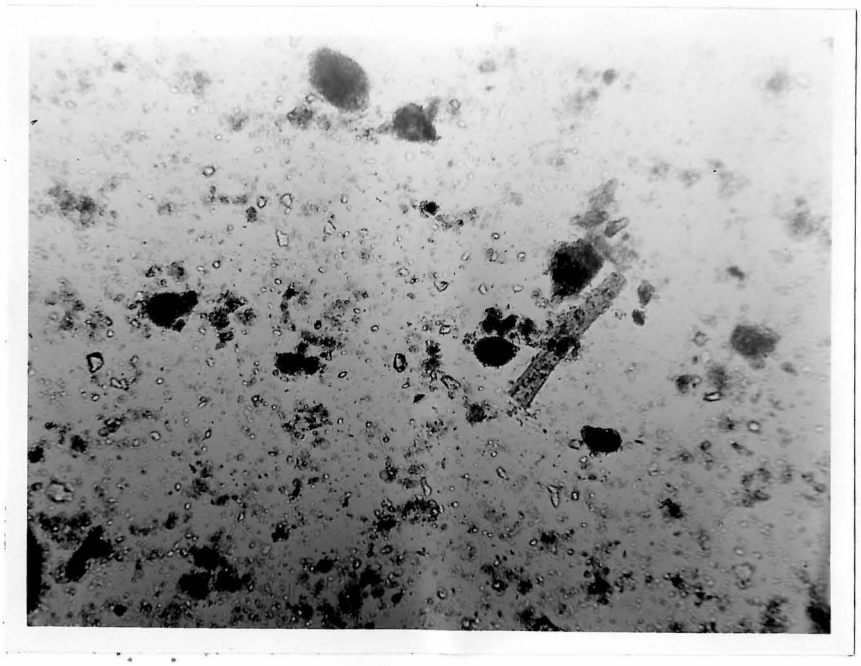
Sample number	Distance between top of core and surface of marsh bottom in cm.	Length of core in cm.	Station number	Total carbon in percent of dry sample
A5.1 A35	0	1	1	6.51
A5.2	2	25		5.87
A5.3	27	7		8.49
A8	72	38		3.99
A9	126	38		3.59
A10	182	38		6.76
A11	242	39		5.26
A12	302	38		7.22
A13	331	39		6.64
A14	358	40		3.95
A34.1	00	2	2	6.13
A15	0	40		6.51
A34.2	2	20		5.62
A16.1	40	20		9.87

Sample number	Distance between top of core and surface of marsh bottom in cm.	Length of core in cm.	Station number	Total carbon in percent of dry sample
A16.2	60	30		13.18
A17	90	50		21.80
A18	140	50		21.16
A27	180	50		17.75
A28	230	50		13.72
A29	280	50		14.22
A30	330	50		12.74
A31	380	50		18.61
A32.1	430	20		14.12
A32.2	450	30		12.65
A33.1	0	2	3	6.26
A19.1	0	25		9.11
A19.2	25	15		Insufficient
A33.2	2	20		7.70

Sample number	Distance between top of core and surface of marsh bottom in cm.	Length of core in cm.	Station number	Total carbon in percent of dry sample
A20.1	40	41		7.68
A20.2	81	9		6.25
A21	90	50		9.66
A22	140	50		7.57

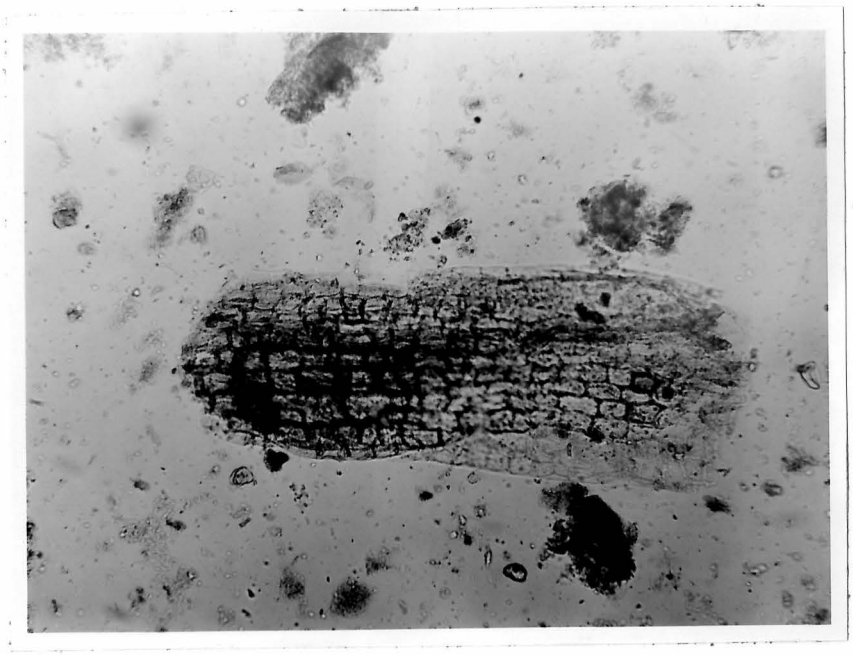


A 23

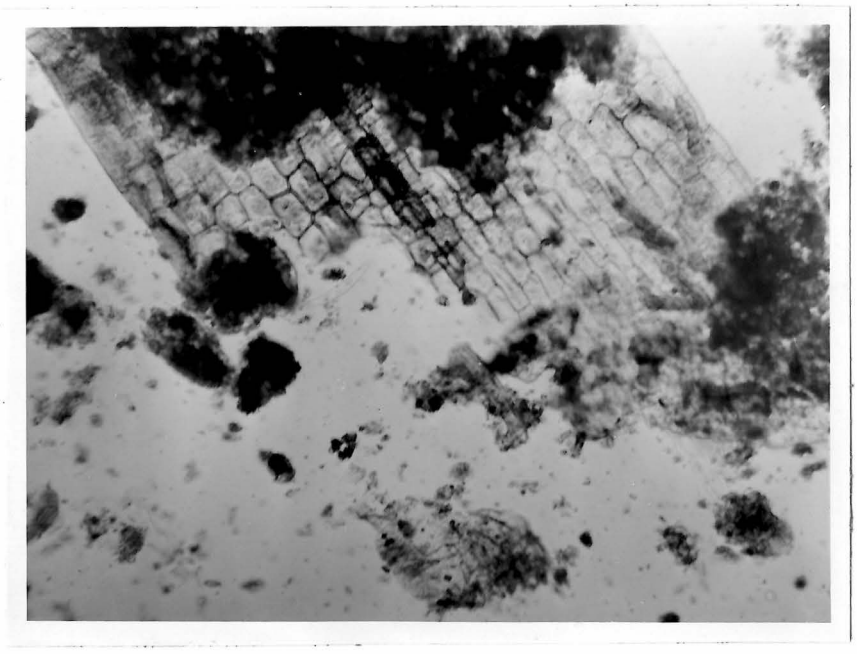


A 24·1

Fig. 8

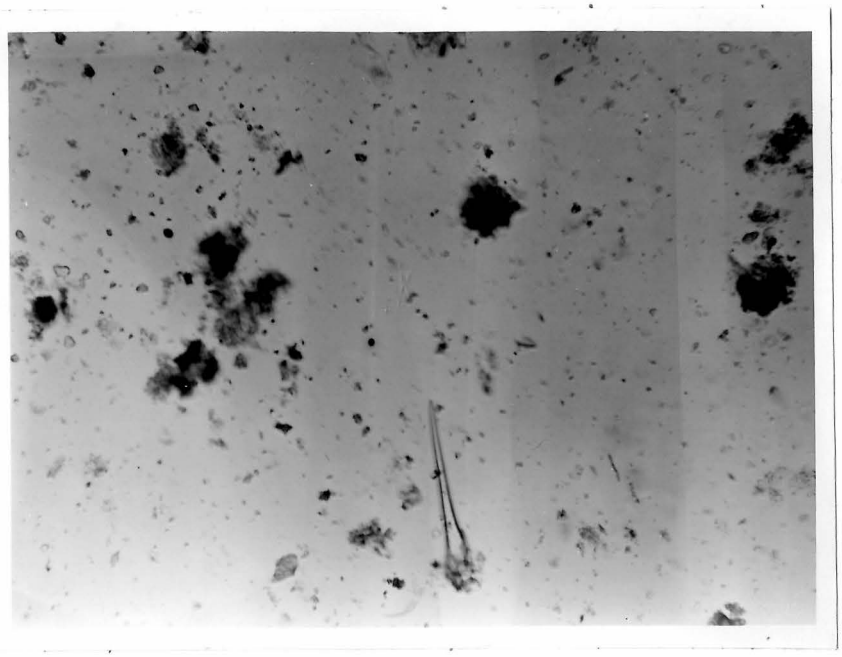


A24·2



A25

Fig. 9



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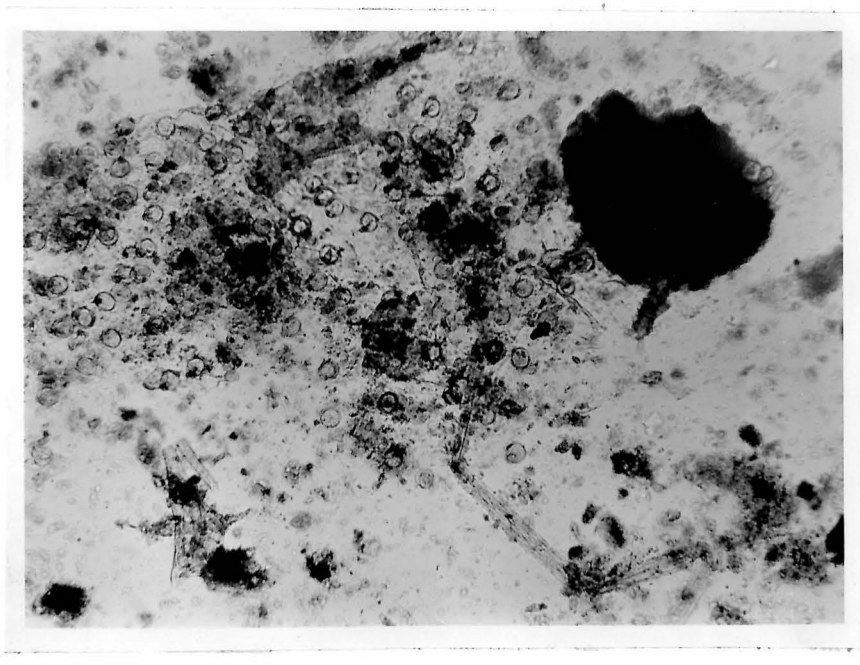
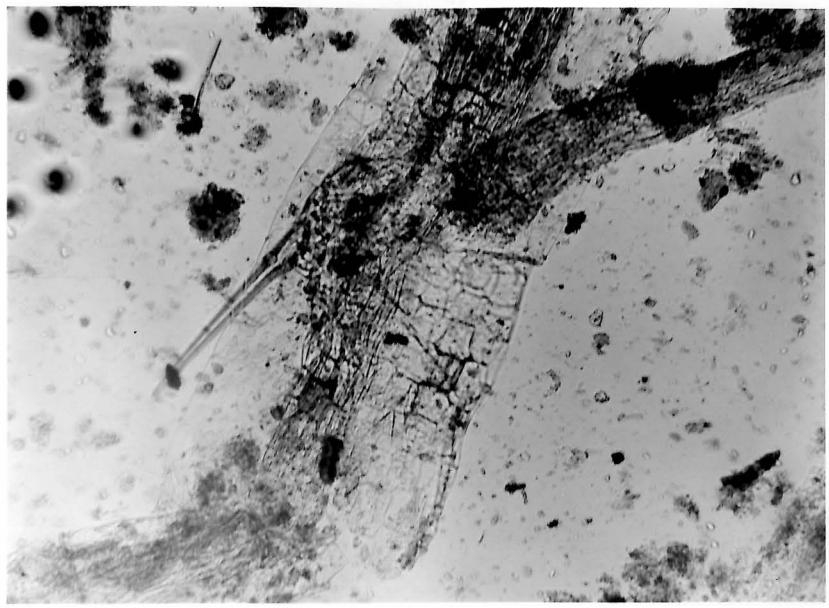
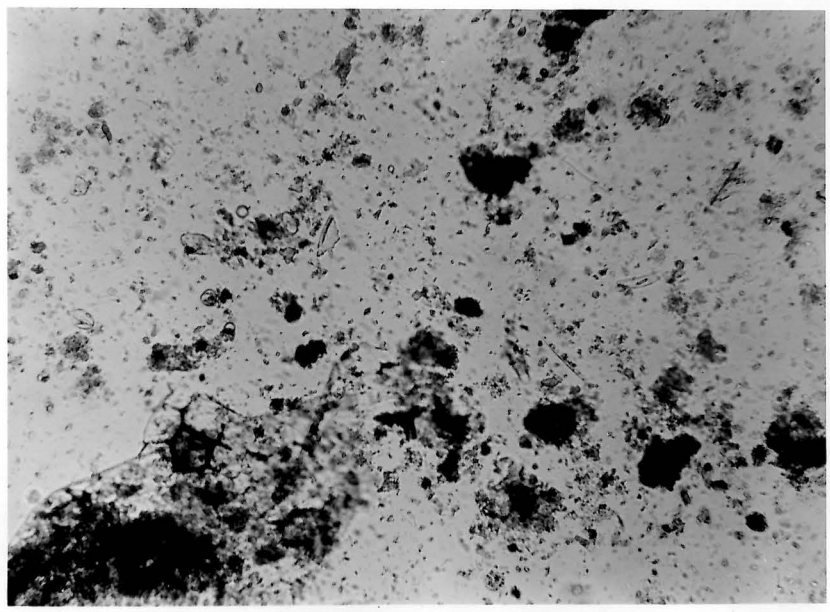


A26

Fig. 10

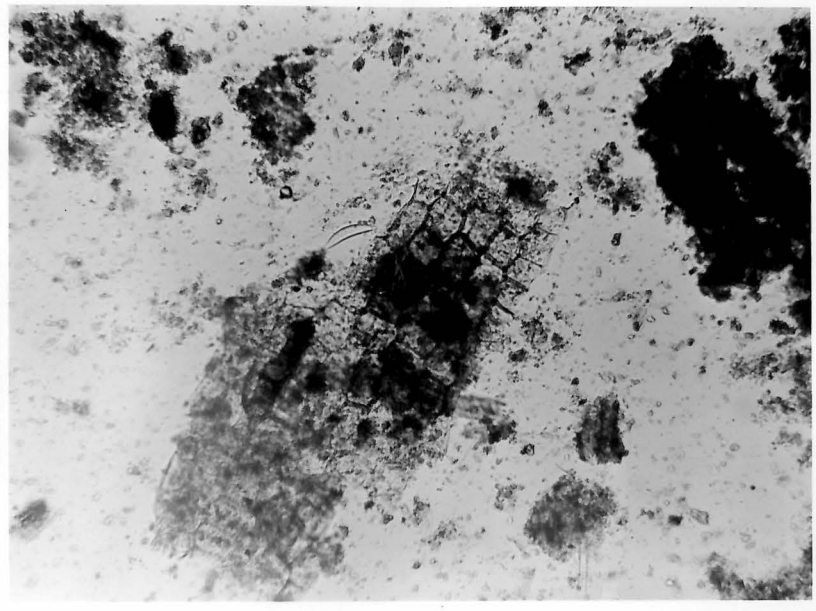


A28

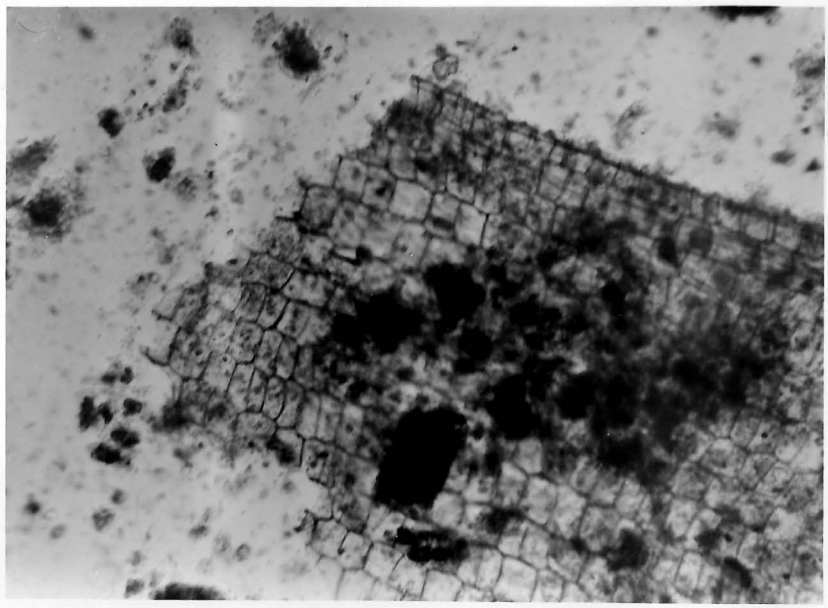


A29

Fig. 11

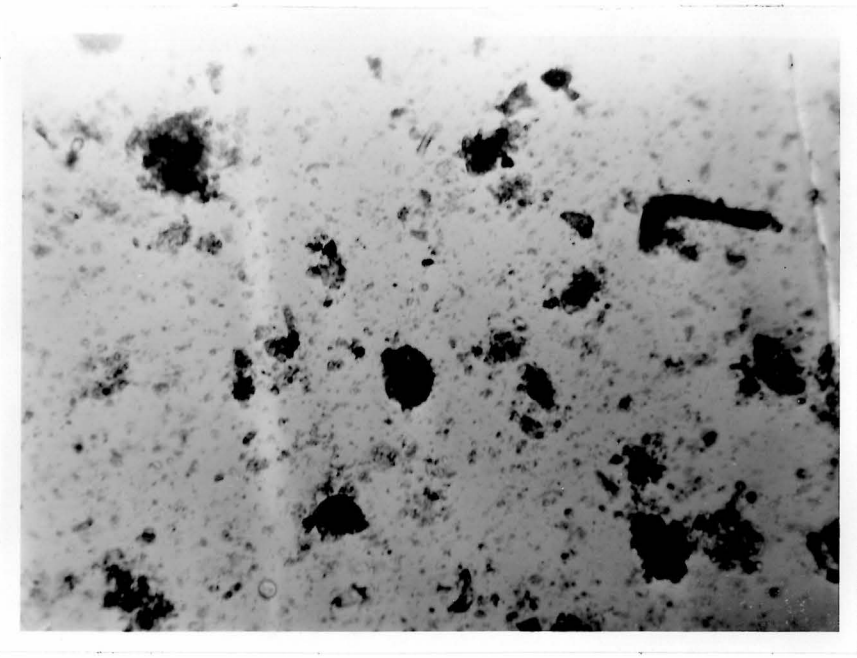


A30

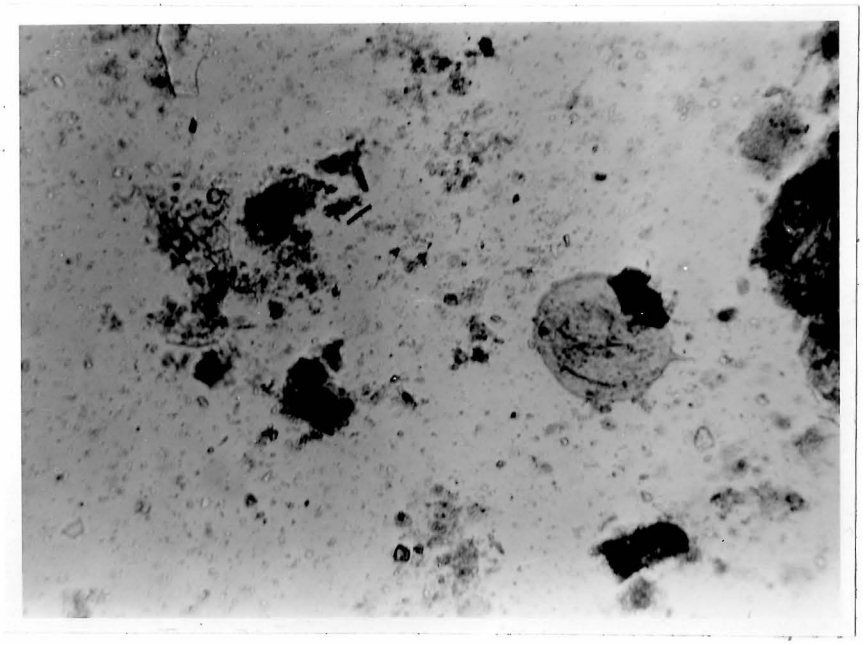


A31

Fig. 12



A32·1



A32·2

Fig. 13

Table 4

Number of sample	Bitumen, Ash protobitumen and fats (D)	Pectins, soluble carbohydrates (F)	Hemicellulose and small amounts of proteins and cellulose (G)	Celluloses, humic acids, lignin and small amounts of proteins (H)
	in percent of dry sediment (B)			
A5.1	82.75 0.34	0.42	11.60	1.04
A5.2	84.82 0.14	3.26	6.38	1.37
A5.3	0.20	2.43		2.07
xA8	86.50 0.15	2.81	5.26	1.61
xA9	89.54 0.10	0.00	8.73	1.13
xxA10	93.04 0.08	0.66	5.22	
A11	89.43 0.06	2.45	0.20	2.97
A12	82.41 0.30	0.92	13.40	0.35
A13	82.81 0.12	1.90	10.85	0.23
xA14	91.66 0.05	0.90	5.81	0.00
A34.1	85.68 0.39	0.77	8.26	1.74
xA15	85.26	0.30	6.18	1.40

Number of sample	Ash	Bitumen, protobitumen and fats (D)	Pectins, soluble carbohydrates (F)	Hemicellulose and small amounts of proteins and cellulose (G)	Celluloses, humic acids, lignin and small amounts of proteins (H)
	in percent of dry sediment (B)				
A34.2	84.78	0.30	3.60	6.18	1.40
A16.1	79.16	1.62	4.68	6.58	2.11
xA16.2	72.13	0.57	6.54	7.93	4.16
A17	55.78	0.63	8.30	8.92	7.04
A18	59.28	2.13	10.51	19.99	1.93
A27	67.60	1.28	7.95	7.29	4.64
A28	28.08	0.80	4.94	54.32	0.00
A29	78.71	0.72	4.48	8.69	1.36
A30	81.28	0.64	1.86	7.76	2.68
A31 A	70.21	0.99	9.18	0.00	7.03
A32.1	75.28	1.32	6.24	0.00	0.00
A32.2	85.36	0.63	3.92	5.82	1.04

Number of sample	Ash	Bitumen, protobitumen and fats (D)	Pectins, soluble carbohydrates (F)	Hemicellulose and small amounts of proteins and cellulose (G)	Celluloses, humic acids, lignin and small amounts of proteins (H)
	in percent of dry sediment (B)				
A33.1	86.95	0.20	0.36	9.62	0.00
A19.1	84.74	0.33	3.53	6.52	0.65
A19.2	Insuff-icient	7.69	8.36	–	4.30
A33.2	82.70	0.40	0.64	11.22	1.53
A20.1	87.23	0.52	4.17	4.65	0.00
A20.2	85.55	0.36	3.28	8.42	1.05
A21	83.26	0.49	4.26	9.29	0.00
A22	82.33	0.62	7.10	1.93	1.48

x Since the weight of the benzene-alcohol soluble substances (C_1) was greater than the dry weight of the sediment (B), C_1 was found by subtracting the value of C (substances soluble in benzene-alcohol) from B.

xx The value for A_4 was incorrect, hence the value of H could not be calculated.

sediment (excluding the universally high 54.32%) while celluloses, humic acids and lignin (H), ranged from 0% to 7.04% of the dry sediment.

(8) The surface sediments had bitumen (D) content from 0.20% to 0.39%, pectins (E) from 0.36% to 0.77%, hemicelluloses (G) from 8.26% to 11.60%, and celluloses and lignin (H) from 0% to 1.74% of the dry sediment.

(9) The highest bitumen content (D) of station 1 was in the surface sample (0.34%); the highest pectin content (F) of 2.81% was in a sample 72 to 110 cm. below the surface of the marsh bottom; the highest hemicellulose content (G) of 13.40% was in a sample 302 to 340 cm. below the surface of the marsh bottom; and the highest cellulose and lignin (H) of 2.97% content was in a sample 242 to 281 cm. below the surface of the marsh bottom.

At station 2, the layer from 140 to 190 cm. had the highest (10) bitumen content (D) of 2.13%, pectin content (F) of 10.51%, and hemicelluloses (G) of 19.99% of the dry sediment. The highest cellulose and lignin content (H) of 7.04% of station 2 occurred in the layer 90 to 140 cm. below the surface of the marsh bottom.

At station 3, the layer from 25 to 40 cm. had the highest bitumen content (D) of 7.69%, pectin content (F) of 8.36%, and cellulose and lignin content (H) of 4.30% of the dry sediment. The highest value of hemicelluloses (G) of 11.22% occurred in the layer 2 to 20 cm. below the surface of the marsh bottom.(Figure 7)

(10) Station 2 had the greatest values of bitumen (D), pectins (F), hemicelluloses (G) and celluloses and lignin (H) in almost every

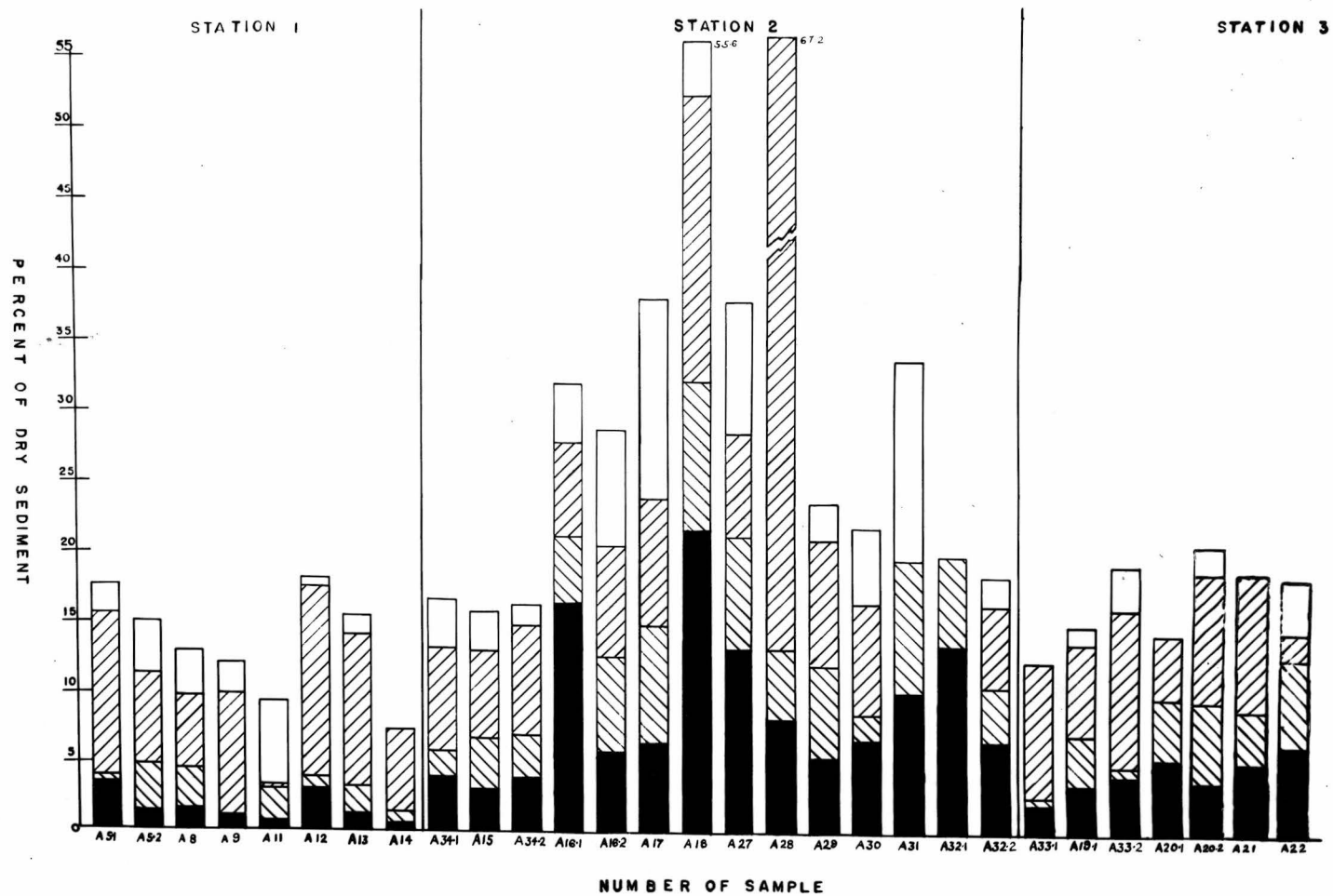

STATION 1
STATION 2
STATION 3
55.6
67.2
PERCENT OF DRY SEDIMENT
0
5
10
15
20
25
30
35
40
45
50
55
A51
A5-2
A8
A9
A11
A12
A13
A14
A34-1
A15
A34-2
A16-1
A16-2
A17
A18
A27
A28
A29
A30
A31
A32-1
A32-2
A33-1
A18-1
A33-2
A20-1
A20-2
A21
A22
NUMBER OF SAMPLE

FIG. 7

LEGEND OF FIG 7

BITUMEN, PROTO BITUMEN AND FATS (D)

MULTIPLIED BY 10

PECTINS AND SOLUBLE CARBOHYDRATES (F)

HEMICELLOSES, PROTEINS, AND SMALL AMOUNTS OF

CELLULOSES

CELLOSES, HUMIC ACIDS, LIGNIN AND SMALL

AMOUNTS OF PROTEINS (H) MULTIPLIED BY 2

layer as compared with stations 1 and 3.

The relationship between the results (Tables 3 and 4, fig. 7) and the level of biological productivity in the Dundas Marsh will not be understood until a larger number of data become available including both organic and inorganic substances of lake sediments.

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